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Cover picture shows the drawing of slag from an electric furnace for producing phosphoric acid in Mt. Pleasant, Tenn., plant of Victor Chemical Works. Other illustrations appear in pictured flow sheet on pages 269-272. [*This cover space released for editorial use by Patterson Foundry & Machine Co.*]

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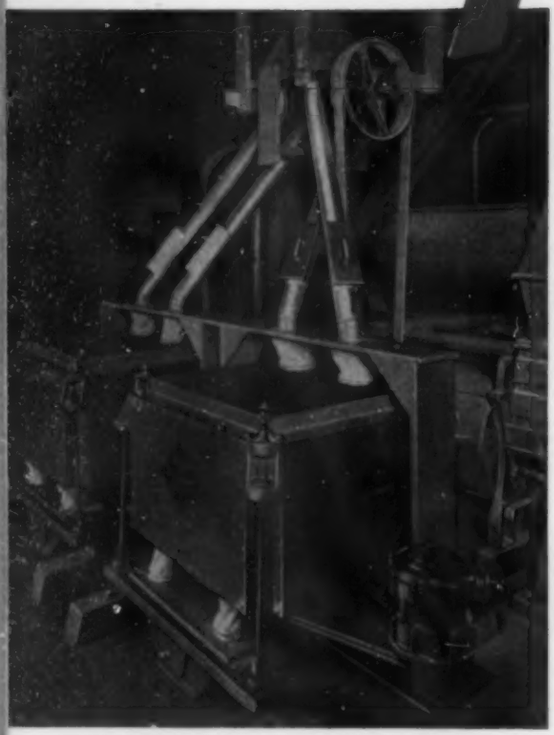

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CHEMICAL & METALLURGICAL ENGINEERING
ESTABLISHED 1902

MAY, 1939

S. D. KIRKPATRICK, *Editor*

Design for Living

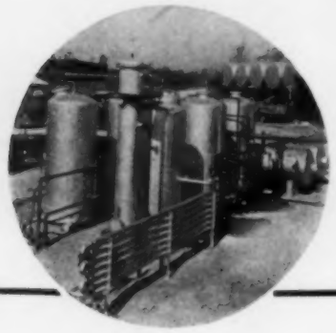
SUPPOSE, FOR A MOMENT, we try to visualize what is probably the most pressing problem we face today, not alone as chemical engineers but as American citizens. Before us is the great surging stream of the unemployed—12,000,000 men and their number ever increasing. On one bank of this river we can picture 1,765 industrial research laboratories, backed by 30,000 trained scientists in our universities and scientific institutions. Across on the opposite shore are our banks, bulging with money—tremendous surpluses of idle funds awaiting profitable investment. To bridge that channel between men and money is Number 1 Engineering Job!

Most of us do not realize that there are 600,000 employable people being added to the working stream each year. In other words, if everyone employed in 1929 had kept his job until 1939 and no new jobs had been created, we would still have 6,000,000 unemployed. Fortunately, a few of our industries, notably some of those in the chemical field, have already gone ahead of 1929 in providing new products and new opportunities for employment. But for most industries there has been a serious lag, due in large measure to the lack of funds for growth and expansion.

Someone in the U. S. Treasury Department has figured out that prior to 1929 the banks (representing the investment public) normally supplied industry with about $4,200,000,000 of new capital each year. In other words, $350,000,000 went back into the business each month to buy the tools with which industry was to grow. Since, on the average, it takes an investment of approximately $7,000 to provide a job for a man in industry, those monthly millions were just enough to take care of the 50,000 new employables that became available each month. In the meantime, of course, the older men and machines were dropping out and our manufacturing efficiency was constantly being increased. In fact, it was this advance of technology that kept us going as a nation.

Today the flow of funds earmarked as "venture capital" is at a very low ebb. Its owners have been thoroughly frightened by costly experiments in government that have burdened us with tremendous debts and taxes. Yet in spite of these discouraging difficulties, science and invention have been exceedingly active during the past decade. There is waiting in our laboratories today a great backlog of undeveloped ideas which might open up new avenues for safe investment and provide new opportunities for gainful employment.

All this is a direct challenge to the chemical engineer. He makes his living most often by translating the results of laboratory research into successful industrial practice. Efficient *design*, economical *construction* and profitable *operation* form the basic trinity of his functions in the world of industry. In most companies, his is the task to present the facts and figures on which money is invested in new products and processes. He occupies a strategic place in America's design for modern living. He can do more than any other to provide employment for the millions.



From an

GREAT MEN OF THE PAST

TWO IMPORTANT CENTENARIES were celebrated this month at the Akron meeting of the American Institute of Chemical Engineers. That organization's president, Dr. Webster N. Jones, has already given *Chem. & Met.* readers (see January, 1939, pp. 14–16) an intimate insight into the chaotic life of Charles Goodyear. In the hundred years since his almost accidental discovery of the process for the vulcanization of rubber, a great industry has grown to exceed even his rosiest expectations. The second centenary noted at Akron was the one-hundredth anniversary of the birth of a great chemical engineer, the late Professor George Lunge of Zurich. His story was well told by one of his most intimate and able collaborators, Dr. Ernst Berl, of Carnegie Institute of Technology (see pp. 258–9 of this issue).

The lives of Goodyear and Lunge offer many interesting contrasts. The former was the intrepid inventor who clung tenaciously to his empirical methods in exhausting every possible avenue of discovery. His many disappointments merely stirred him on to further experiments. While others were profiting through his great inventions, he was thrown into prison for his debts and died in 1860, broken in health but ever an experimentor.

George Lunge was primarily a scientist and engineer rather than an empiricist. Like Goodyear, he was an indefatigable worker—averaging 15 hours per day for more than 40 years of his active life. While Lunge contributed many inventions, none as revolutionary as Goodyear's discovery, yet all helped to advance technology in chemical industries. By far the greatest contributions of Lunge, however, were his books and his students. The former first gave the world the basis for a practical literature of chemical technology. The latter were missionaries who quickly spread from Switzerland to Germany, England, France and America, inspired to build up chemical industries in these countries based on Lunge's methods and discoveries. The cumulative effect of all these activities was tremendous and when the great teacher died in 1923, he could not only look back on a fruitful life but was already assured that the influence of his books and his work would continue as long as there was chemical industry in the world.

Goodyear and Lunge had in common the unselfish desire to benefit mankind—ignoring personal gain that their ideas might take root and grow. The one, an empiricist and the other, an engineer, left us an heritage that all chemical engineers may well cherish.

NEW EXECUTIVE QUALIFICATIONS

BUSINESS MUST CHOOSE its new bosses by a different criterion than formerly. "We must continue the current (social) shift in the emphasis of business thinking." This is the conclusion of Representative Bruce Barton in his interpretation to the U. S. Chamber of Commerce of new considerations which now prevail in selecting business executives.

He pointed out that sometime ago a company president was a production man, because production was the most pressing problem. Then came the period when a financial man was needed, because more capital was the problem. Later the sales manager was most likely to control. Then, he says:

"The top man of the future will be the man who knows people, likes people, and thinks day and night in terms of better public relations. If industry puts people first and keeps them first in its thinking, we shall not again fall under the blight of suspicion and resentment."

Chemical engineers will want to study this philosophy, and perhaps adjust their thinking and planning correspondingly. Those who succeed in adapting themselves to the new industrial needs will have just as good a chance to become president of their company as ever before. But without this adjustment we fear that the best engineer will stay "just a hired man."

COOPERATIVE BUYING

AN EXCEEDINGLY LARGE part of rural purchasing is now being done through co-ops. These purchasing agencies are believed to do at least half a billion dollars worth of business per year, through approximately 3,000 organizations. This is an industrial market that may no longer be ignored.

A great many chemical commodities and

Editorial Viewpoint

products of chemical process industries go, or should go, to the members of these co-ops. Those enterprises which find the most economic plan for delivering their goods to the co-ops are likely to get this business. Merchandisers of process industry may profitably investigate this situation anew these days.

It is not quite evident how sulphuric acid, or alkali, or some of the rare synthetics can find any benefit from this new unit in merchandising. But there is every reason to believe that soon somebody is going to make real advances for his firm in the selling of cement, or fuel oil, or anti-freeze, or a multitude of other consumer products, in such a fashion. The fact that we have never done business that way is no longer an excuse for losing this chance at profitable merchandising.

PROFESSORIAL PATENTS

SEVERAL educational institutions have formulated plans by which there can be joint handling of the patents that result from the research of their faculty members. To a certain extent this has been a constructive thing. It has often helped members of faculties who could not alone have cared for their projects as well as did the industrial groups. It has made for cooperative action where otherwise controversy might have prevailed. But it has also injected two dangerous factors.

In at least one case of which we are confidentially informed, an important university lost the opportunity to have established on or near its campus a great research undertaking. Those who were planning to sponsor this research learned that if any faculty man had anything to do with the projects, there might be a question as to whether the university itself would not in some measure own or control the resulting patents. The purpose of the research project was constructive and could have legitimately utilized the expert cooperation of certain faculty members. But the sponsors did not dare risk the possibilities of institutional interference. The research will be done elsewhere.

The second difficulty which has been noted is not so clean cut, but a few instances of serious complication are reliably rumored. Certain faculty men who think themselves potentially important inventors are resenting the fact that there is a tendency to force them to surrender their private patent rights to the educational institution. Even in one case where the patent plan is merely "voluntary," the pressure on individuals to pool with others has been so great as to be almost compulsory.

All this should be a warning to industry, to the educational institutions, and to faculty men. Industry cannot tie up with professors as consultants or for cooperative research without determining what is the patent relationship of the man to his institution. Faculty men must inquire of their employers as to the expected relationships on the patents where any pooling scheme is tried. And the institution should go very slowly with such projects, making sure that the overall results are of real public benefit, not merely superficial and subsidized aid to private parties. Mismanaged patents can kill the goose that lays the golden eggs.

ANOTHER PIONEER PASSES

DR. FREDERICK W. FRERICHS, a pioneer leader in the chemical industry and profession, died in St. Louis April 30 at the age of 90 years. Born in Germany, he had received his Ph.D. degree at the University of Goettingen in 1874 and for five years served as assistant to Professor Friederich Woehler. Dr. Frerichs came to the United States in 1880 and was chemist and superintendent of the Mallinckrodt Chemical Works in St. Louis until 1886. For the next 45 years he was director and officer of the Herf and Frerichs Chemical Co. of St. Louis. A charter member of the American Institute of Chemical Engineers, he was its president in 1911 and treasurer from 1912 to 1926.

Dr. Frerichs early interested himself in the subject of chemical engineering education and served as chairman with William M. Booth, George D. Rosengarten, F. G. Wiechmann and A. A. L. Veillon, of the committee which reported its findings at the first meeting of the Institute in Niagara Falls in 1910. This report, published in Volume III of the Transactions of the Institute, may well be regarded as one of the first significant milestones in chemical engineering education in the United States.

To Award Chemical Engineering

Announcing plans for the fourth of the biennial awards sponsored by Chemical & Metallurgical Engineering to encourage outstanding group effort in chemical process industries.

IN THE DARK DAYS of 1932 it was common observation that those companies which best withstood the devastating effects of the depression were those that had consistently invested in research and new product development. Furthermore, they were characterized by a most constructive attitude toward their technical men. Chemists and engineers were not regarded as skilled artisans to be hired and fired with every turn of the business cycle. Rather, they were encouraged to participate broadly in all the affairs of the industry. In such companies the work of the chemical engineer was not confined solely to the design, construction and operation of equipment and processes, but he was encouraged to share in executive responsibilities for production and sales, management and administration.

In the hope that other companies in the chemical process industries might be encouraged to adopt a similar attitude toward their technical men, *Chem. & Met.* in May 1933 established its biennial Award for Chemical Engineering Achievement. It was expressly stated that this award should be given to a *company* rather than to an *individual* since its primary purpose was to recognize the coordinated group effort that results from this broader participation of the chemical engineer in the affairs of the chemical process industries.

First company to be selected by the Committee of Award in 1933 was the Carbide and Carbon Chemicals Corp. in recognition of its important achievement in the building of a great synthetic aliphatic chemicals industry in this country—a typically American development based on American research. Two years later the second award was made to the Organic Chemicals Department of E. I. du Pont de Nemours & Co., Inc. Here the outstanding chemical engineering achievement was the commercial production of two essential raw materials for American industry—synthetic rubber from acetylene and synthetic camphor from American turpentine. The most recent award was presented in 1937 to the Monsanto Chemical Co. for its contribution to the large scale production of elemental phosphorus. This has proved the basis for greatly broadening the application of phosphorus derivatives and has helped to open a new field for chemical engineering products and processes.

As in preceding years, the fourth Award for Chemical Engineering Achievement will be made to that company which, in the opinion of the representative committee of recognized leaders in the industry and profession, has contributed the most meritorious advance "made possible by the broader participation of the chemical engineer in the affairs of the chemical process industries." This committee, under the chairmanship of Dr. Webster N. Jones, president of the American Institute of Chemical Engineers, will welcome suggestions from all readers of *Chem. & Met.* Please address all correspondence to the Secretary, Committee of Award, *Chemical & Metallurgical Engineering*, McGraw Hill Building, 330 West 42nd St., New York, N. Y.

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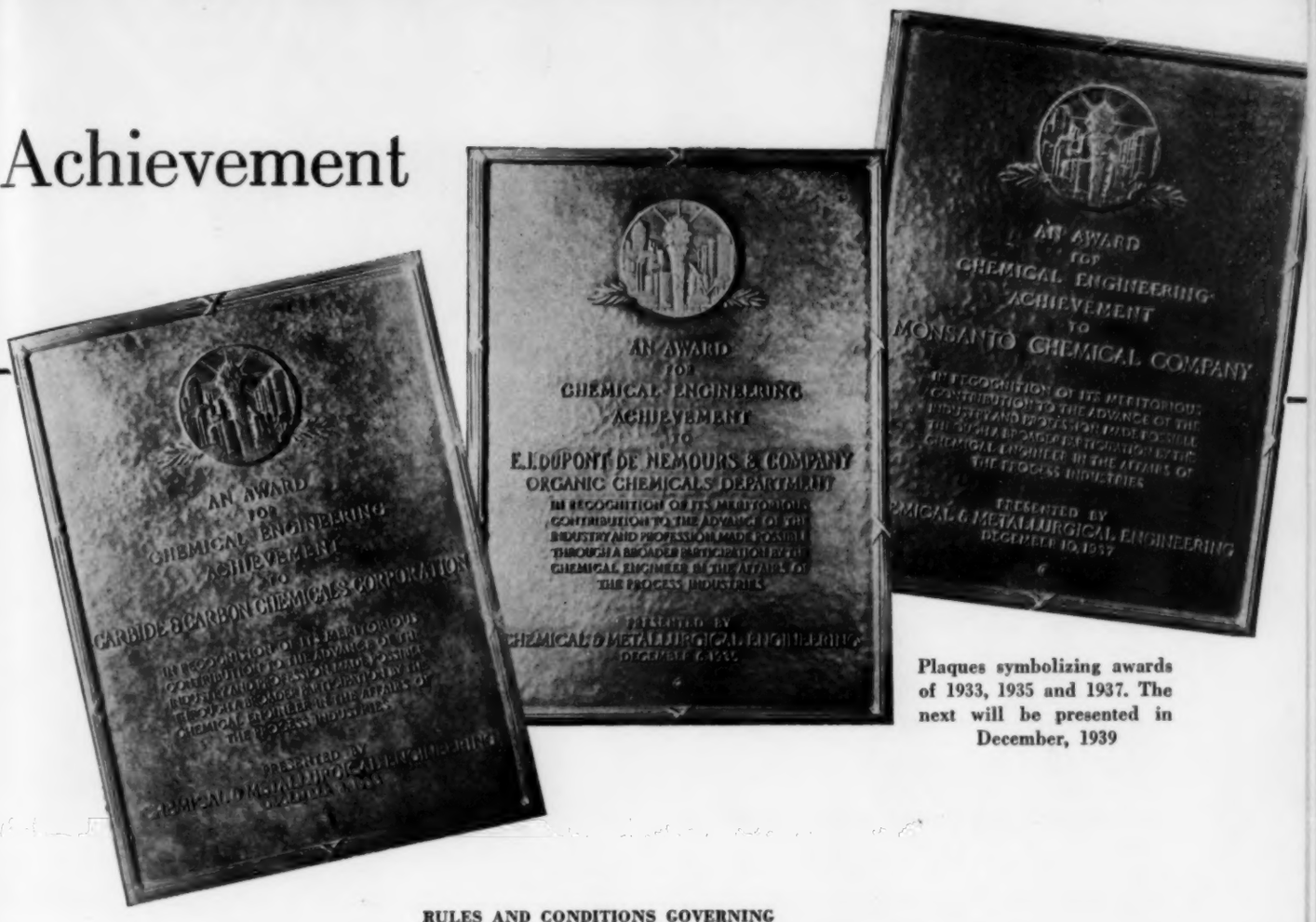
Achievement



Plaques symbolizing awards of 1933, 1935 and 1937. The next will be presented in December, 1939

RULES AND CONDITIONS GOVERNING

AWARD FOR CHEMICAL ENGINEERING ACHIEVEMENT

1. The purpose of this award is to give public recognition to that company in the chemical process industries which, through the effective use of chemical engineering in any phase of its activities, has contributed the most meritorious advance to the industry and profession during the period under consideration.

2. The award consists of an appropriate bronze plaque suitably engraved to indicate the nature of the achievement and the name of the company to which it is presented. The Fourth Award for Chemical Engineering Achievement is to be made at the time of the National Exposition of Chemical Industries which will be held in New York City during the week of December 4, 1939. This award applies only to industrial developments that have come to fruition since December, 1937. Subsequent awards will be confined to developments occurring in the intervals between the National Expositions of Chemical Industries.

3. The award is to be made only to a company in the process industries since it is a recognition of the achievement of a corporate organization rather than that of any individual within a company. However, any company or any of its subsidiaries would be eligible for the award on the basis of any number of achievements brought to the attention of the Committee.

4. The Committee of Award shall consist of nine men, recognized as leaders in the industry and profession. One of the members of the Committee is to be designated as its chairman, and the editor of *Chem. & Met.* is to serve as secretary of the committee but without voting power. It is expressly understood that no member of the committee will be asked to pass on the merit of entries made by any company with which he is affiliated. In other words any member would have the privilege of withdrawing at any time should the consideration of a company's name prove likely to be embarrassing in personal or business relations. In such cases the member of the committee would be reported as "not voting."

5. It is to be the function of the Committee to review the achievements of the chemical process industries, to receive suggestions from all sources and to determine which company has, in its judgment, contributed the most meritorious chemical engineering advance during the interval under consideration.

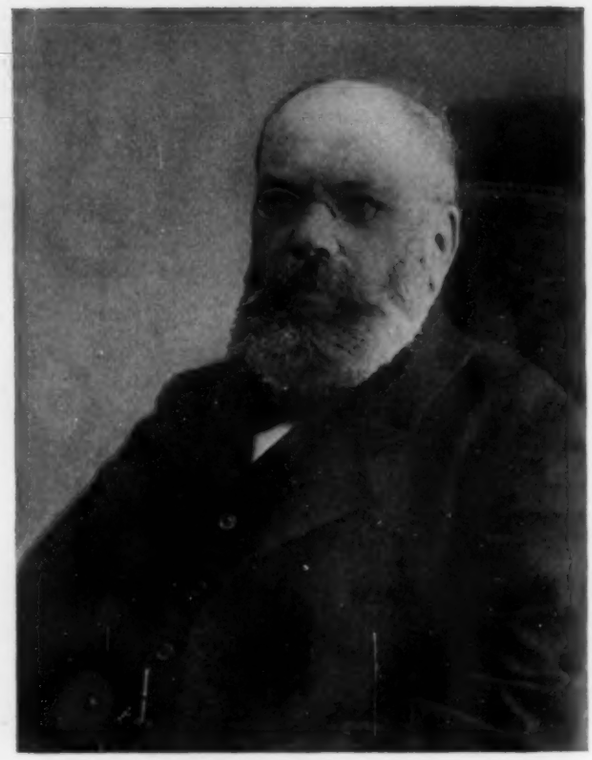
6. Any company in the chemical process industries desiring to be considered for this award may file an application merely by answering the following inquiries:

(a) What is the nature of the achievement?
(b) During what period was it effected?
(c) To what extent have chemical engineers participated in this development?
(d) Are there any supplementary records, data, articles or references which should be included as pertinent to a fair consideration of this achievement?

7. It is expressly understood, however, that this award is not limited to those companies which file formal applications with the Committee. Suggestions are desired from any and all sources that will assist in directing the attention of the Committee to achievements of companies that should have consideration. All communications should be addressed to the Secretary, Committee of Award, *Chemical & Metallurgical Engineering*, McGraw-Hill Building, 330 W. 42nd St., New York, N. Y.

George Lunge

CHEMICAL ENGINEER



Born in Germany 100 years ago next September 15, this great pioneer in our profession left a lasting impression on the heavy chemical industries of the world. His story is vividly told here by one of his last but most able collaborators.

ERNST BERL

Research Professor
Carnegie Institute of Technology
Pittsburgh, Pa.

BEFORE CITING some of my distinguished teacher's great deeds as a chemical engineer, it may be necessary to define that term. Is a chemical engineer a man who knows so little chemistry that the chemists say he is an engineer, and who knows so little engineering that the engineers say he is a chemist? Or is a chemical engineer one who in a single person combines these two very important disciplines so that he may do creative work and may be in a position to carry out his own or other men's laboratory experiments and ideas on a large scale in order to produce the most favorable results for industry? I believe the latter definition is the true one for the chemical engineer and if we accept it, then certainly Lunge was one of the first and most successful of our profession.

To do justice to a man like George Lunge and his accomplishments, one must consider the status of industry 80 years ago when he entered it. The first editions of Lunge's classical books, written in the sixties and the seventies of the last century, give some idea of how far-reaching has been the progress since that time, especially in the field of materials. Those technicians who had to solve their problems then met extremely great difficulties because the construction materials at their disposal were so inferior to what we have today. Yet, in spite of all these difficulties, they accomplished work which, even today, commands our respect and admiration.

Lunge had a great critical sense for technical achievements. In 1865, when but 26 years of age, he was the first to recognize the extreme importance of the Glover tower in sulphuric-acid manufacture by the chamber process. At that time it was meeting with exactly the same indifference and opposition as had the Gay Lussac tower that had been invented in 1827 but had not been used until 13 years later. Lunge, in several publications, soon convinced most of his contemporaries that they were wrong in opposing this great progress. We can see the same attitude in several other cases.

In the so-called "Lunge-Rohrmann plate reaction tower," Lunge himself introduced a very important invention into the chemical industry. Through his classical studies of the lead chamber process, he had found that the speed of reaction at the entrance of the first chamber was rather high and at the opposite end was rather small, that the speed of reaction was again increased in the connecting tubes and at the beginning of the next chamber. So in 1886, as a result of his researches, he designed a tower composed of a series of horizontal, perforated plates and introduced this plate tower instead of one or more chambers in the lead chamber system. He was thus able to get the effect of much larger chambers. This Lunge tower was used for many years not only in the sulphuric acid industry but also in many other fields where heterogeneous reactions between gas and liquid had to take place. In several instances this reaction tower gave an effect twenty times better than that from a coke-filled tower of the same dimensions. Today packed towers have replaced

Extracts from an address before the American Institute of Chemical Engineers, meeting at Akron, Ohio, May 15, 1939.

these plate towers, but we see that the basic idea of Lunge to increase the surface of contact between gas and liquid was essentially sound.

Following our definition of a chemical engineer, that he should be a creative man who should know how to execute other people's ideas as well as his own, the interesting story of the production of sulphuric acid monohydrate may be mentioned. When Lunge attacked this problem in 1882, the modern contact oleum processes started by Clemens Winkler were unknown. One hundred per cent sulphuric acid, known in industry and science as sulphuric acid monohydrate, was badly needed by the dyestuff manufacturers. It was known that through concentration of a diluted sulphuric acid it was possible to obtain only a 98.3 per cent acid and this only with a tremendous expense in fuel. Lunge's idea was to concentrate sulphuric acid in platinum concentration apparatus to about 94-97 per cent, which could be done with a reasonable cost for fuel, and then to submit this strong acid to low temperature whereby the sulphuric acid monohydrate crystallizes. It can be separated easily by centrifuging from the 91 per cent sulphuric acid in the mother liquor. Today, of course, this process has lost its importance because the monohydrate can be made much cheaper by mixing oleum with 66 deg. Baume sulphuric acid. We should not forget, however, that chemical processes, like all things in nature, are born and grow and finally perish.

Bronze plaquette designed by Hans Frei, in 1909 on occasion of Lunge's 70th birthday

In 1886 Lunge built the Federal Chemical Laboratory in Zurich which now, after 53 years, remains a modern and efficient institution. During this period of his activity Lunge certainly was the most famous teacher in chemical technology, not only to his students, but also to those thousands all over the world who got their information from his many publications and books. His first book on "Coal Tar and Ammonia" (1867) was published in four editions up to 1912. Then followed "Sulphuric Acid" and "Soda Industry," published from 1878 to 1916 in four editions, which became, literally, the bibles of every heavy chemical technologist. It is really amazing how Lunge collected this great amount of information and data, practically without the help of collaborators and certainly without the assistance of our modern abstract and patent journals. Part of the answer is found in the fact that for more than 40 years of this activity, Lunge regularly worked more than 15 hours every day.

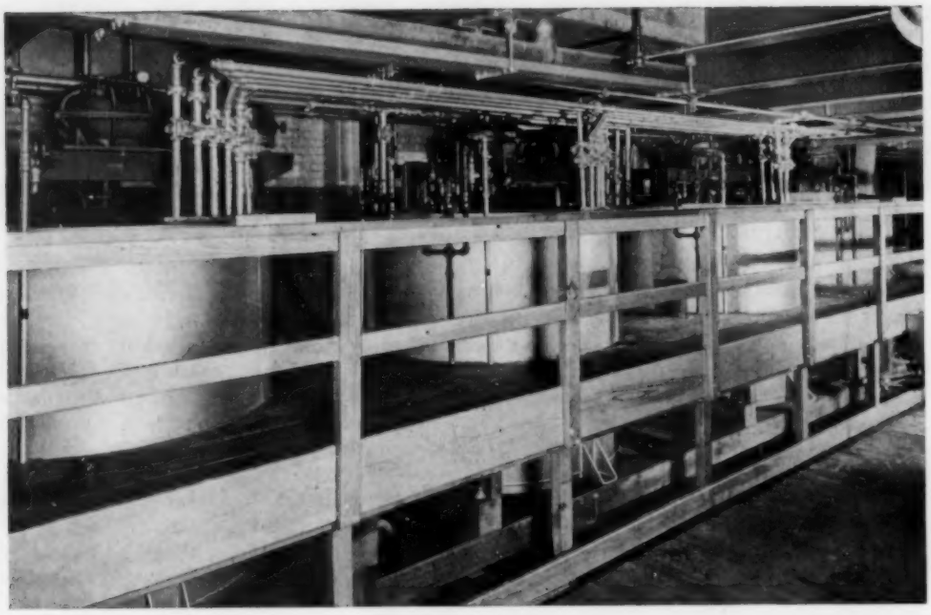
Lunge was always interested in and invented many new analytical methods. He improved many existing procedures by replacing empiric and very often inexact methods by more efficient procedures.[1] The first two editions of Boeckmann's "Technical Methods of Chemical Analysis" were edited by Boeckmann, the third, fourth and fifth editions by Lunge himself, the sixth with the writer, and the seventh and eighth by the writer alone after Lunge's death. This book, now in five volumes, covers practically the whole field of chemical technical analysis. Lunge also edited the "Handbook for the Inorganic Chemical Industry." The fourth, fifth and sixth editions were published with the writer and the seventh after Lunge's death.

The value of the research work which Lunge did in a great many different fields cannot be over-estimated. His great love, of course, was the lead chamber process. On another occasion the writer had the honor to present a paper showing some of the latest developments growing out of work in this interesting field. (See *Chem. & Met.*, November, 1934, "Pressure Synthesis, a Possibility for Sulphuric Acid Manufacture," by E. Berl, pages 571-5). Lunge studied the role of iron oxide as a catalyst in the contact oleum process which is of importance in the so-called Mannheim process.

Lunge's own practical experience in the soda industry in England, especially with the Leblanc process, resulted in a very important study of bleaching powder and the role of the hydrogen ion in the decomposition of hypochloric acid to form chlorides and chlorates. Lunge was perhaps the first who insisted that the yellow phosphorus in the match industry had to be replaced by the less poisonous red phosphorous or phosphorsesqui-sulphides. Lunge's experimental work on the theory and practice of the production of water gas was very important. It brought light into the question of how to operate during the so-called "hot blowing" period in order to form carbon monoxide or carbon dioxide.

When Lunge entered the chemical industry in 1860, it centered largely around the lead-chamber and the Leblanc soda processes. The British chlorine industry was developed by the Lord Derby Act in 1865. Practically all hydrochloric acids from the sodium sulphate production had to be condensed. The Weldon process, with its regeneration of manganese compounds, was developed in 1866, and soon afterward one of the first heterogeneous catalytic processes, the Deacon-Hurter process (1867), came on the scene. During Lunge's long life he was to see all of these and many other processes change and develop to yield the basis of our modern chemical industry. From 1860 until his death in January, 1923, he kept actively in touch with all of this progress. There have been many great men among his collaborators and contemporaries in the field of science and industry but none has left behind such a diversified record of achievement in the field of chemical engineering.

[1]The writer well remembers some of those changes. Once he entered a concentration plant for sulphuric acid which was being used for the recovery of alcohol and ether. The foreman spat in each of the heated basins made from lead and filled with sulphuric acid. Asked why he did this, his answer was: "You see, the acid should not be stronger than 60 deg. Baume. Below this strength it does not sizzle. So I have to regulate the flow according to what happens." Or there is a nice story of Count Chardonnet's ducks. In the Hungarian nitro-rayon plant two kinds of waste liquids, waste acids and alkaline polysulphides and nitrites resulted. They had to be neutralized so that the final liquid could be drained into a small river. The neutral water was stored in a pool. As long as it was neutral, ducks entered into it and swam. When the pH was higher or lower than 7, the ducks did not enter the pool. The control of the mixture of waste liquids was possible only with the help of the pH-determining ducks.



Monel sulphonating, neutralizing and washing equipment used in producing textile oils and other chemicals

Protection Against Sulphuric Acid

Much new information on the corrosion resistance of Monel metal to sulphuric acid in the production of ammonium sulphate, the sulphonation of oils, the splitting of fatty oils and in other operations has been collected and is reported here for the first time

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EXPERIENCE has shown Monel to be one of the most satisfactory metals for handling sulphuric acid. This alloy finds its principal applications at concentrations of less than about 80 per cent by weight and in this range it usually offers a very satisfactory combination of corrosion resistance and mechanical properties. At these strengths corrosion is extremely low if the acid is air free, and even in the case of 5 per cent acid which is saturated with air and at room temperature, maximum corrosion is less than 0.04 ipy (inches penetration per year).

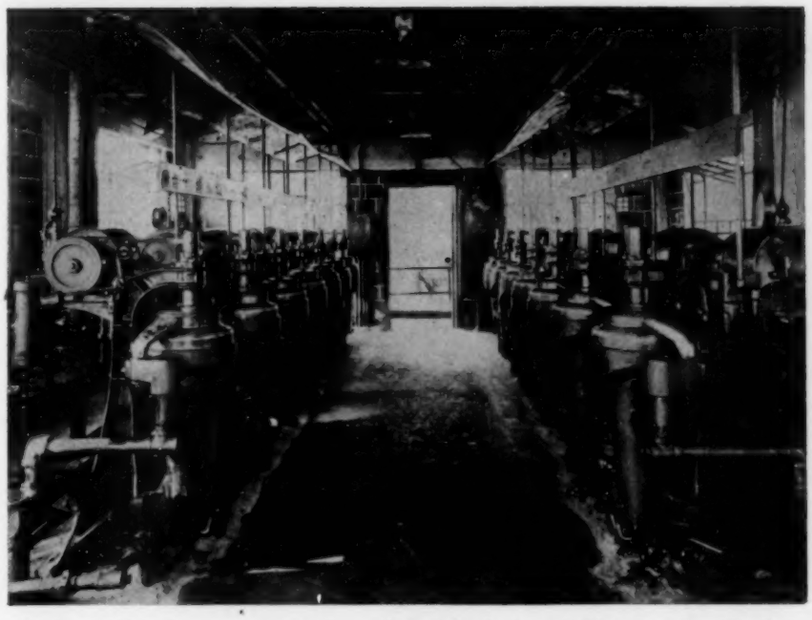
The normal effect of increasing temperature is to accelerate corrosion. However, the lower solubility of dissolved oxygen at elevated temperatures may cause a decrease in corrosion rates above some critical temperature determined by the concentration of the acid which in the case of 5 per cent acid is at about 176 deg. F. When the concentration of oxidizing substances is low, increasing temperature, will have little effect below the boiling point, in acid under 60 per cent concentration. Corrosion rates in boiling solutions are likely to be somewhat erratic due to complex effects associated with dissociation of the acid in contact with the metal. In such cases it is the best practice to test the metal under exact conditions of use.

Increasing velocity may be expected to increase corrosion. Corrosion products of Monel in sulphuric acid are soluble and usually afford no protection to the metal, although in certain industrial applications the formation of non-metallic films may afford protection. The presence in the acid of appreciable quantities of some highly oxidizing soluble salts, particularly those of iron and copper, may be expected to increase corrosion markedly.

Applications in Industry

Sulphonation is usually accomplished with 66 deg. Bé acid at temperatures ranging from 80 to 90 deg. F. It may require from four to fifteen or more hours, depending upon the size of the batch and composition of the oils. In many cases, the acid treatment is followed by washing and neutralization in the same equipment,

The experimental data reported in this article were collected by Mr. Friend from tests conducted by the Research Laboratory and Technical Service Division of the company.



Bowls of Sharples super centrifuges bored from forged Monel rods. Used in continuous acid treatment of cylinder stock

requiring that the equipment resist not only the strong acid but dilute acid and sodium hydroxide as well. The results of corrosion tests in several operating sulphonators are given in an accompanying table. Due to variations in the duration of the sulphonation process, the results have been reduced to a common basis and expressed as "inch penetration per 100 batches." The test conditions varied somewhat, but those of Test No. 3 were typical. In this test each batch required 2,200 lb. of oil and 500 lb. of 66 deg. Bé acid and lasted fifteen hours. The temperature was 80 to 90 deg. F. In all the tests except Nos. 7 and 8, the sulphonation was followed by water washing and neutralization with caustic as a part of the procedure. Tests 7 and 8 were made during sulphonation only.

Monel is used for the construction of complete sulphonators, linings, heating coils, and other miscellaneous equipment, such as agitators, pipe and fittings, and pumps and pump rods.

The ultimate use of most sulphonated oils calls for a product of high purity, free from discoloration. Users have observed that oil sulphonated in Monel equipment is usually as true in color as oils processed in glass. In the case of olive and tea seed oils, practical experience has shown nickel and Inconel to be the generally preferred materials.

It is important to note that in these processes the low corrosion rates are due not only to good resistance to attack by the acid, but also to the fact that the metal surface is protected for part of the time by a film of oil.

Fat splitting is generally done either with twitchell reagent (sulphobenzene stearic acid) plus a small quantity of sulphuric acid, or by sulphuric acid alone, both processes employing moderately elevated temperatures. Monel may be expected to corrode in a typical twitchell process at a rate of less than 0.01 inch per year of continuous exposure. Inconel is comparable to Monel, with nickel somewhat less resistant. In straight sulphuric acid splitting, the corrosion rates of Monel, nickel, and Inconel have also been found so low as to be practically negligible. Such data as are available indicate that Inconel is somewhat superior to Monel in the high-temperature, high-pressure autoclave process.

A common process for the manufacture of ammonium sulphate is the direct system by which gas from the coke ovens, after cooling and removal of tar, is reheated and delivered directly into saturators. In these, the ammonia reacts with sulphuric acid, the temperature running as high as 140 deg. F.

Monel is employed in modern saturator pumps for all parts coming in contact with the acid mother liquor and the crystals. Pump casings, discharge elbows, and discharge pipes are likewise made from this alloy. In the saturator, these parts are either submerged in the hot acid sulphate liquor, of from 6 per cent to 20 per cent sulphuric acid concentration, or subjected to acid fumes and spray. Wide use is also made of Monel

CORROSION TESTS IN OIL SULPHONATION *

Solution — Various oils and various quantities of 66° Be H_2SO_4, followed by washing and neutralization, except Tests 7 and 8. Location of Tests — Immersed in liquid. Approximate Temperature — 16° to 60° C.

Material	Average Corrosion Rates Inch Penetration per 100 Batches (a)							
	Test 1 During 16 Batches	Test 2 During 20 Batches	Test 3 During 25 Batches	Test 4 During 14 Batches	Test 5 During 40 Batches	Test 6 During 36 Batches	Test 7 (b) During 70 Days Ipy. (d)	Test 8 (c) During 60 Days Ipy. (d)
	Cod Liver Oil	Tallow, Red, Castor and Olive Oils	Castor and Olive Oils	Neatsfoot and Fish Oils	Castor Oil, Tea Seed Oil and Olive Oil	Olive and Red Oils	Animal and Vegetable Oils	Animal and Vegetable Oils
Monel	0.0005	0.0005	0.0008	0.0050	0.0006	0.0002	0.0024	0.0005
Nickel	0.0011	0.0019 (p)	0.0010	0.013 (p)	0.0010	0.0007	0.0032	0.0013
Inconel	.....	0.0012	.....	0.018	0.0017	0.0004	0.0027	0.0008

* Tests at several plants.

(a) Production varies considerably, hence to standardize the results this unit has been chosen, unless otherwise stated. Average production may run 150 to 250 batches per year. Each batch averages 12 to 24 hours.

(b) Test 7 was made in a sulphonator with no neutralization of acid-oil mixture.

(c) Test 8 was made in neutralizing and wash tank taking oils from sulphonator in Test 7.

(d) The exact number of batches processed is unknown, hence corrosion rates are expressed as inch penetration per year.

(p) Significant local attack in the form of pitting.

baskets, wire cloth linings, wear plates and fastenings of centrifugals, employed for the extraction of ammonium sulphate mother liquor and the drying of sulphate crystals.

A study of the resistance of Monel to corrosion by ammonium sulphate mother liquor containing 9 per cent acid at 190 deg. F. revealed that the loss in weight was equivalent to 0.006 ipy. A similar test, but in liquor of above 158 deg. F. showed for Monel a corrosion rate of 0.004 ipy. This test was extended to measuring the weight loss of an operating all-Monel basket. It was found that, per 1,000 tons throughout, the Monel basket lost only 2.5 per cent of its original weight. Based on previous experience with other materials this was considered by the user to be an exceptionally good performance. Similar observations have been made with other Monel basket installations.

Among the most important applications of sulphuric acid in the textile industry are: its use in the preparation of acid baths used principally in the dyeing of wool and silks, for wool carbonizing, textile scouring, the preparation of viscose rayon hardening baths, and for the shrinking, washing, and dyeing of felt hats.

There are two different methods employed for the chrome tanning of hides—the two-bath process and the one-bath process. In the former, the hides are treated first with acidified sodium dichromate solution and then with acidified sodium thiosulphate solution. The one-bath process utilizes a liquor containing basic chromic sulphate which effects the tannage in a single operation. Dilute sulphuric acid is used in preparing all of these solutions.

Corrosion data for Monel from tests made in numerous chemical manufacturing processes and solutions containing sulphuric acid are presented in tabular form.

Corrosion of Monel in Boiling Sulphuric Acid Solutions

Acid Conc. % by Weight	Boiling Temp.		Corrosion Rate		Duration of Test
	° C.	° F.	Mdd.	Ipy.*	
5	101–102	214–216	16–232	0.0026–0.0378	22–23 hr.
10	102	216	15–1315	0.0024–0.2140	23 hr.
19	104	219	46–708	0.0075–0.1150	23 hr.
50	123	253	3180	0.518	23 hr.
75	182	360	10,400	1.70	23 hr.
96	290–295	554–563	20,150	3.28	3 hr.

* Ipy. = Inch penetration per year (assuming corrosion from one side of metal only). In the case of Monel 100 mdd. = 0.0163 ipy.

Corrosion Tests in Acid Washing of Fatty Oils

Solution — (1) Animal oil and ¾% H_2SO_4 solution.—(2) Oleic acid and ¾% H_2SO_4 solution. Location of Tests — Immersed in liquid and at liquid level. Temperature — Atmospheric to boiling. Duration of Tests — 38 Days.

Material	Average Corrosion Rates Ipy.	
	Solution (1)	Solution (2)
Monel	0.0012	0.0004
Nickel	0.0012	0.0012
Inconel	0.0009	0.0003

CORROSION TESTS IN TWITCHELL PROCESS FOR FAT SPLITTING *

Solution — Mixture of fats or oils, 1 to 1½% H_2SO_4 and twitchell reagent. Location of Tests — Immersed in liquid, and at liquid level. Temperature — Tests 1 to 6 up to boiling.—Test 7—70° to 82° C. Duration of Tests — 6 to 83 Days.

Material	Average Corrosion Rate Inch Penetration per Year								
	Test 1 83 Days	Test 2 65 Days	Test 3 38 Days	Test 4 6 Days	Test 5 61 Days		Test 6 43 Days	Test 7 (a) Storage — 61 Days	
	In Liquid	In Liquid	At the Liquid Level	At the Liquid Level	At the Liquid Level	In Liquid	In Liquid	At the Liquid Level	In Liquid
Monel	0.0025	0.0026	0.0031	0.0089	0.0022	0.0007	0.0027	0.0003	0.0004
Nickel	0.013	0.018	0.0087	0.037	0.015	0.0096	0.0092	0.0018	0.0015
Inconel	0.0050	0.0049	0.0027	0.018	0.0042	0.0030	0.0085	Less than 0.0001	Less than 0.0001

* Tests at several plants. (a) Storage of acids from twitchell process splitting.

RESULTS OF CORROSION TESTS WITH MONEL IN TANNERY OPERATIONS

Operation	Conditions of Test				Corrosion Rate Ipy.
	Location	Duration	Liquor	Temperature	
Pickling	Pickling vat	91 days	Salt brine — sulphuric acid solution adjusted to pH of 1.5.	Boiling when being prepared, room temperature for balance of time.	Less than 0.001
Vegetable Tanning	Tanning drum (specimens exposed to splash)	344 days	Quebracho extract, concentrated; and pickling solution made up from 30 lb. of sodium chloride to 50 gal. of water and adjusted to pH of 1.5 by addition of sulphuric acid.	Max. 50° C. for 2% of time, 32° C. for 80% of time, balance room temperature.	0.0015
Chrome Tanning "One Bath Process"	Tanning vat with rocker arms; specimens in vat immersed in liquid and subject to agitation.	350 days	Chrome tan liquor approx. .75% Cr_2O_3; 1.10% H_2SO_4 max. (prepared by reducing a sodium dichromate-sulphuric acid solution with glucose in a separate tank) — No pickling in same vat, but hides were also neutralized with sodium bicarbonate, borax or soda ash and then washed in running water.	13° to 20° C.	0.0006
	Tanning drum	29 days	Prepared solutions of reduced chrome tan liquor made up from sodium dichromate, sulphuric acid and glucose, and alternate exposure to sulphuric acid-salt brine pickling solution.	Room.	0.0015
Coloring	Tanning drum (specimens subject to splash).	343 days	Dye solutions, basic, acid and direct colors applied with acetic, formic and sulphuric acids.	Room temp., to a maximum of 50° C.	Less than 0.001

Method for Emulsifier Choice

Despite numerous attempts to reduce mixing and emulsification to a science little progress has been made. The author now shows a rational method of emulsifier choice employing principles which may eventually lead to the solution of mixing problems other than emulsification. The method has been proved by extensive use.

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SELECTION of equipment for the commercial production of emulsions has long been carried out by empirical methods, if not by guess work. Consequently some formulations have never been achieved on a factory basis while others have been produced inefficiently. However, the selection of equipment for emulsification processes need not be haphazard, for a method has been developed whereby, on the basis of experiments in laboratory equipment, the equipment best suited to commercial production for a particular emulsion can be determined. The method has been applied successfully to a great number and variety of emulsification problems. Since the theory on which it is based is broadly applicable to the general field of mixing, it is possible that the method may eventually point to a similar procedure for handling general mixing problems.

An emulsion is a pseudo-homogeneous dispersion of one liquid in another in which it is immiscible. In the case of a mixture of two miscible liquids, complete homogeneity will be attained, regardless of the character of the liquids, if sufficient time is permitted to elapse. A mixture of immiscible liquids, however, can reach the desired level of homogeneity only upon the application of shear. The determination of the rate and quantity of shear needed to produce a given emulsion most efficiently is the problem considered in this discussion.

The mechanism of emulsification is not well understood. However, the following explanation appears to stand up in the light of present knowledge, and it has the advantage of permitting the attainment of the desired results. In addition to the components of the emulsion, commercially useful types require the presence of a colloidal substance known as the emulsifying agent which may be present naturally or may be added intentionally. This agent is adsorbed or concentrated at the interface between the phases. Application of shear to the mixture causes the phase which shows the greater surface tension in contact with the emulsifying agent to gather into globules sheathed in a film of the agent. This shearing must be continued until the dispersed phase has been reduced to the desired level of particle size and uniformity and the total shear required for this purpose represents a definite and calculable amount of work, depending on the viscosity. (The derivation of the expression for this work is relatively simple, being based on the fact that the force required to shear a particle of diameter D is equal to $vD\pi t$, where v is the viscosity or resistance to shear and t is the average thickness of the particle at the point of shearing action. Neglecting the distortions which accompany shearing action, the reduction of a volume of the dispersed phase of V to an ultimate particle size s requires theoretically an amount of work equal to $W = v\,\pi\,[2s \times (3/4\pi\ V)^{\frac{1}{3}}]^{3/2} \times 3V/[4\pi\,(s/2)^3]$. Particularly is this equation useful in determining approximately the work required in extraction mixing. Since real emulsions are rarely formed in such cases, and surface charging is small, the total work may be calculated taking V as the volume of the dispersed phase.

In addition to the work absorbed by the shearing process, some of the work applied to the mixture goes to the production of surface charges on the emulsifying agent film and it is the mutual repulsion of these charges which maintains the dispersion. The quantity of work for this purpose depends on the dielectric constant of the film, but cannot be calculated directly.

This shearing process, however, cannot be applied solely to the dispersed phase, but is applied to the entire mixture so that the total work depends upon the mixture viscosity. In transmitting work through the mixture to the dispersed phase, part is lost in the production of heat in the two phases. Simultaneously, another part acts to charge the continuous phase, thus producing a de-emulsifying tendency. Thus, under a given set of conditions there exists a dynamic equilibrium between emulsification rate and de-emulsification rate, with part of the work usefully applied in emulsification, and part wasted in producing heat and de-emulsification.

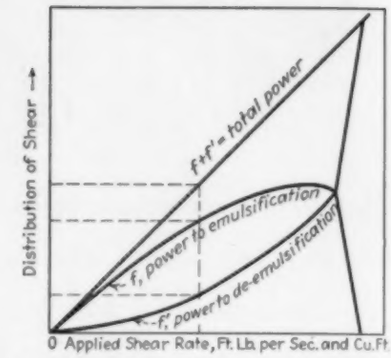
From this it might appear that the higher the rate of shear (power) applied to the mixture, the shorter the emulsification period. This is true only within limits, however. For each type of emulsion there is a maximum rate of shear which can be used since the emulsifying agent envelopes will not accept surface charging at more than a certain maximum rate. Beyond this rate of shear the electrostatic charging of the continuous phase increases, thus increasingly neutralizing the surface charges of the dispersed phase and shifting the emulsification —de-emulsification equilibrium toward the right. Furthermore, at higher rates of shear more power is lost as heat and the effect of higher temperature, while it reduces the

work of the mechanical shearing, is also to increase the resistance to the charging of the dispersed phase. Thus it is clear that the problem is to determine that rate of shear which will yield the maximum actual emulsification rate, while reducing heat production and de-emulsification to a practical minimum.

When the dispersed phase has reached a certain level of particle size, further work on the emulsion will not further reduce the particle size nor improve the stability of the emulsion. Instead, the de-emulsification tendency will continue while the emulsification tendency ceases and the continuation of shear application for a sufficient time will neutralize the dispersed particle charges and permit the coalescence of the dispersed phase, thus "breaking" the emulsion. How much work is necessary to break the emulsion cannot be determined directly, but a thermodynamic consideration shows that it cannot be greater than the work which went into shearing and charging the dispersed phase originally. Where W is the work of emulsification; W' the work of the de-emulsification; f the power going to emulsification; f' the power going to the de-emulsification; T the time for completing emulsification; and T' the time for emulsification plus de-emulsification, then $W = fT$ and $W' = f'T'$. Furthermore, assuming the two works equal, $W = W'$ and $fT = f'T'$ or $f/f' = T'/T$. That is, if the work of de-emulsification equals that of emulsification, then the ratio of emulsification rate to de-emulsification rate is inversely as the times during which the two operations continue. As will later be shown, an increase in the rate of shear application will increase the percentage of the total work acting to produce de-emulsification, an increase which can be measured inferentially by comparison of the ratios T'/T for two different rates of shear. This increase in de-emulsification rate may be exceedingly gradual, giving an emulsion which is not sensitive nor prone to "overshearing." On the other hand, it may be exceedingly rapid, giving a sensitive or "delicate" emulsion which may be incapable of formation in equipment imparting the higher rates of shear. That is, with too great a rate of shear for a particular emulsion, the wasted energy may equal or even exceed the work applied usefully in emulsification, and no emulsion will be formed.

An idealized picture of what is presumed to happen in a typical emulsion appears in Fig. 1, which charts f, the part of the power applied to the emulsification; f', the part applied to de-emulsification; and their total $f+f'$, against increasing rate of applied shear. Characteristically, a point is reached where the two tendencies are equal, after which the power applied to emulsification decreases rapidly to zero. Fig. 2 shows this information in different form as $R = f/f' = T'/T$—that is, as the ratio of emulsification rate to de-emulsification rate—plotted against increasing rate of applied shear.

Assuming that these data were derived from an actual emulsion, Fig. 2 would show that at a rate of total power input of Hp_1, the ratio of emulsifying rate to de-emulsifying rate (which is also the ratio of T' to T) was $R = 6$; at Hp_2, 3.3; and at Hp_3, 2.1. It has been found empirically that with the great majority of emulsions, the most efficient rate of shear application is that which produces a value of R of approximately 1.2. This is far enough along on the f-curve in Fig. 1 to prevent accidental encroachment on the region where de-emulsification rate equals and later exceeds emulsification rate, and yet falls close to the point where the power employed for emulsification is a maximum. Consequently, the problem in studying an actual emulsion is to discover that rate of shear which will yield approximately this desired ratio.


Distribution of Shear
f+f' = total power
f, power to emulsification
f', power to de-emulsification
0 Applied Shear Rate, Ft. Lb. per Sec. and Cu. Ft.

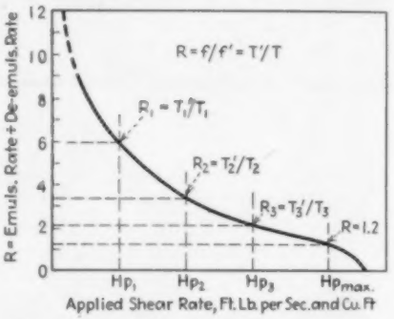


Fig. 1—Idealized diagram showing distribution of shear with increase in total power applied to an emulsion mixture

Fig. 2—Ratio of f and f' curves of Fig. 1 vs. power increase

Determining Shear Requirements

Ordinarily, this is quite simply accomplished. Using a small laboratory mixer of the paddle type having a low peripheral speed (not over 300 ft. per min.), the minimum time is determined, first to set up an emulsion of the desired particle size, then to break it in the same equipment. At such a low rate of shear, the breaking time may be excessive, even several days or weeks, so that if breaking requires more than ten times the emulsification time, this value may be used with sufficient accuracy. The average horsepower during the test is also recorded. Then, when T_1' is the time to make and break the emulsion; T_1 is the time to make the emulsion; and Hp_1 is the average power input during the test, T_1'/T_1 is the value of R_1 at the rate of power input employed and $T_1'Hp_1[1 - T_1'/(T_1' + T_1)T_1'Hp_1]$ is the work which was used in shearing and charging the dispersed phase.

Now, either by speeding up the mixer (2 to 2½ times), or by employing a mixer capable of imparting an equivalent higher rate of shear, determine the same factors again with the same volume of mixture, recording T_2', T_2 and Hp_2. In this instance, $T_2'/T_2 = R_2$ and if the difference of $R_1 - R_2$ is considerable, a delicate emulsion is indicated (See Fig. 2) and best results are obtained by making a third test at a still higher rate of power input. If then the three values of R are plotted against the horsepower as in Fig. 2, it is an easy matter to estimate at what rate of shear (Hp_{max}) the curve would reach a value of $R = 1.2$. However, if the change in R in the first two tests is slight, an insensitive emulsion is indicated in which case D, the delicateness factor (that is, the rate of change of R with increasing power application), may be calculated from the expression $D = (R_1 - R_2)/(Hp_1 - Hp_2)$. Then $Hp_{max} = Hp_1 + (R_1 - 1.2)/D$ for the test batch, or $N\ Hp_{max}$ for a commercial batch N times the volume of the laboratory batch, produced in whatever type of equipment will apply the desired rate of shear. Fig. 3 shows the approximate capabilities of various types of emulsifying equipment for applying shear. Deter-

mine the viscosity of the emulsion mix and the value of Hp_{max} expressed in ft.lb. per cu.ft. of emulsion mixture. The intersection of these two values on the chart shows the type of mixer best suited to the problem. Should the intersection fall between two mixer types, then the performance of the lower type may be raised or that of the higher type lowered, by one of several methods below.

Should it prove impossible with the paddle type mixer to obtain the desired particle size in the dispersed phase, then either another type of equipment capable of imparting a higher rate of shear must be used; or the mixture is incapable of emulsification because of chemical composition or incorrect method of manufacture. Use of a laboratory colloid mill will show which of these situations obtains. If the colloid mill produces a satisfactory emulsion, the values of R_1 and R_2 (and R_3 if necessary) can be determined by using different plate-to-plate clearances.

Types of Equipment

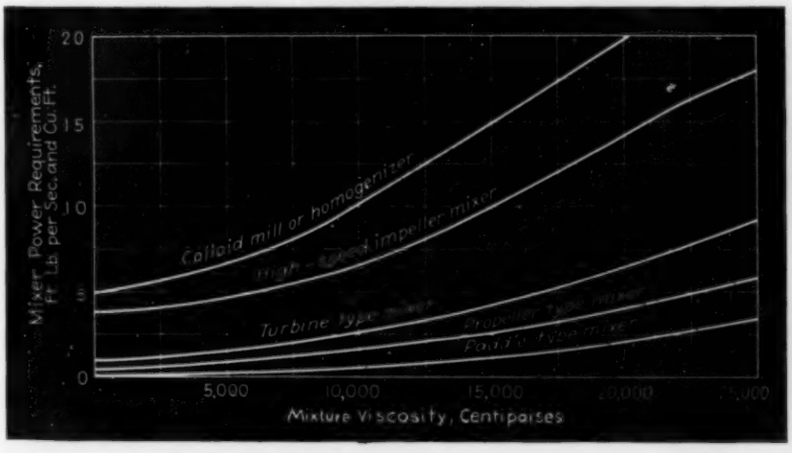
A few words about the types of emulsification equipment are desirable at this point. On the one hand are the general types exemplified by the names of paddle, propeller, turbine and high-speed impeller plate type mixers, and on the other hand are colloid mills and homogenizers. Relatively high rates of shear are imparted by equipment of the latter class in comparison to the former. Since the former types impart lower rates of shear, they are better suited to emulsions having a high degree of sensitivity (high delicateness factor) while emulsions with low delicateness factors are better handled in the latter group. In the first group the factors which determine the rate of shear of which the equipment is capable include (1) the number and peripheral speed of the rotors used; (2) the ratio of rotor diameter to container diameter; (3) the extent of "baffling" against swirl and similar effects; and (4) effective plate area of the propelling or impelling rotor. As has been explained before, the power requirement of the machine is actually a measure of the rate of shear which it can produce. This fact applies also to colloid mills and homogenizers, both of which are capable of various rates of shear depending on adjustment.

It is clear from the above that a limited degree of control of the rate of shear capable of being exerted by any one type of machine can be exercised by changes in design or adjustment, as well as in the speed of the machine. Mixers of the first class, for example, can be altered by changing the peripheral speed, altering the ratio of rotor diameter to kettle diameter, altering the effective blade area, or any combination of these. Colloid mills can be adjusted by changing the plate-to-plate clearance, and homogenizers by altering the valve loading.

In conclusion two other factors entering into a study of emulsion should be mentioned. Emulsions are classed as "permanent" and "temporary." A temporary emulsion is one produced as an intermediate step in a process, which is later to be broken. Numerous cases are found in heterogeneous reaction systems, extraction mixtures and "flushed" pigment formulations. The purpose here is not to produce an emulsion, but rather to secure the most intimate possible contact, with separation of the phases at the end of the process. The problem, therefore, is to approach as close to a stable emulsion condition as possible without actually reaching the stage where the emulsion is stable or difficult to break. The highest possible shear intensity should therefore be determined, consistent with a satisfactory separation, and the intensity of shear required to produce a permanent emulsion also determined, to be used as a limit which must not be too closely approached.

A permanent emulsion, on the other hand, is not necessarily one which demonstrates lasting quality, but rather is one which embodies in itself the end-purpose of the operations which led to its production. Obviously, this paper has dealt largely with permanent emulsions but there is one phase of the question, quite similar in nature to the treatment of temporary emulsions, which remains to be mentioned. This is the factor of "pre-mixing." Most emulsification operations proceed in two stages, in the first of which the emulsion mixture is established on a low or superficial level of homogeneity; and in the second, the distribution and further subdivision of the dispersed phase continues to the desired degree of fineness and uniformity. These two stages may not be easily defined and may even occur simultaneously within the same batch. However, when the stages are separate, the first may differ largely in power requirement from the second, or the two may differ by little or nothing. If the first condition holds, pre-mixing in one piece of apparatus and completion in another is usually indicated. In such case the shear requirements of both phases should be determined as indicated above. Particularly is pre-mixing desirable when finishing is accomplished on a colloid mill or homogenizer. Several advantages are to be noted. The higher the level of homogeneity established in the pre-mixture, the less is required of the finishing equipment and the higher its capacity. Secondly, it is generally true that the higher the level of homogeneity attained in the pre-mixer, the less likely is occurrence of spotty or local overshearing. Consequently, work done to determine the most suitable pre-mixing equipment and optimum pre-mixing time is well worth while.

Fig. 3—Typical power requirements for various emulsifier types at varying viscosity



Ever Consider a Synthetic Rubber?

Akron meeting of the American Institute of Chemical Engineers weighs advantages and disadvantages of the new rubber-like materials, particularly in their use when designing equipment for chemical process use.

SYNTHETIC RUBBERS are featuring, as we go to press, one of the symposiums at the Akron, Ohio, meeting of the American Institute of Chemical Engineers. Extensive abstracts of papers dealing with four of these materials are given here. Other papers presented at this meeting will appear in early issues of *Chem. & Met.*

Pyroflex

Pyroflex constructions for acid and alkali service were discussed by C. A. Rauh, Maurice A. Knight, Akron, Ohio. This is a thermoplastic material having a depolymerized colloid resin base introduced by Maurice A. Knight. It adheres by fusion to all clean metal, concrete, wood, glass and ceramic surfaces. It is flexible and non-tacky over a wide range of temperatures and will not check or crack with severe thermal shock. In dielectric strength it is approximately equal to hard rubber. Hardness and flexibility can be altered with compounding within certain limits.

This product is manufactured in sheet form ⅛ in., ¼ in. and ⅜ in. thick, 30 in. wide and 48 in. long. The sheet is non-porous and entirely homogeneous. There are no plies or layers of any kind used to add strength or bulk. Several grades are manufactured to adapt the material for specific operating conditions. An entirely different compound is required for a tank operating at boiling temperatures from a lining for storage vessel operating outdoors in severe cold and subject to exterior physical bumping. Maximum flexibility coupled with sufficient stability to carry the weight or pressure involved is desired in any operation.

Pyroflex is applied by progressively fusing the sheet to the tank wall, ceiling or bottom. An oxyacetylene torch or a large blow torch is used to preheat the cemented surface of the tank and to preheat the sheet. The sheet is

EDITORIAL STAFF

liquefied to a depth of approximately 1/32 in. when being applied either by progressively rolling forward or by pressing in place.

Briefly, the important constructions worked out to date are enumerated as follows:

(1) Plain Pyroflex linings.
(2) Pyroflex linings with interior brick or tile or slab sheathing.
(3) Pyroflex linings with sheathing of brick and with inner separate ceramic construction designed especially for heat insulation.
(4) Pyroflex strip and ceramic linings as applied to chrome plating tanks.
(5) Special ceramic shapes.

Generally, plain Pyroflex linings will handle practically all acids which are not strong oxidizing agents, all salts, and caustic soda up to 70 per cent. This material is recommended for use at temperatures up to 160 deg. average and 200 deg. maximum. Special compounds of Pyroflex are flexible at 10 deg. F. Plain Pyroflex linings are being used for muriatic acid storage tanks, fume ducts, stacks and washers, ventilators, hoods and sewers. Process tanks handling food products treated with muriatic and sulphuric acid and caustic soda are lined with Pyroflex which does not contaminate these products by odor or taste and prevents formation and growth of bacteria. Among the other uses of plain Pyroflex linings are:

(1) Paper mill chlorinator towers,
(2) Paper mill tail and feed boxes.
(3) Bleach liquor (hypochlorite) manufacturing and storage tanks,
(4) Rayon process tanks,
(5) Water softener tanks and softened water storage tanks,
(6) Alum storage and mixing tanks,
(7) Muriatic acid treatment tanks for brine,
(8) Caustic soda storage and process tanks.

Plain Pyroflex linings are not generally recommended for temperatures over 180 deg. F. average or 200 deg. maximum. Organic solvents such as turpentine, benzol, castor oil, gasoline, kerosene, lubricating oils, carbon bisulphide, carbon tetrachloride, etc., cannot be handled in plain Pyroflex linings. Strong oxidizing agents such as chromic acid, nitric acid over 7 per cent and concentrated sulphuric acid cannot be safely handled in plain Pyroflex linings. Neither is this type lining recommended for abrasive conditions.

The following are typical service conditions for which this construction is satisfactory:

(1) Bright nickel plating tanks
(2) Concentrated sulphuric acid stripping tanks
(3) Paper mill chlorinator towers
(4) Electrolytic tanks for refining copper, zinc and lead
(5) Wash machine basins, sumps, pits, troughs and sewers for plate glass works
(6) Gold and silver refining tanks
(7) Muriatic acid system coke boxes
(8) Acid-proof floors, for wear, and to carry loads up to 50 lb. per sq. in.

With proper choice of ceramic carbon brick materials and careful use of the correct type of acid-proof cement the fused on brick Pyroflex construction can be used to handle any acid condition without exception at any concentration or temperature up to 250 deg. F.

Neoprene

Neoprene (polymerized chloroprene) is a material of construction

which, when vulcanized, closely resembles soft, vulcanized rubber in its physical properties but displays quite different chemical properties. This product was described by E. A. Bridgwater of E. I. du Pont de Nemours & Co., Wilmington, Del.

In order to develop any one property of rubber or of neoprene to the optimum extent, it is usually necessary to sacrifice other properties; hence, the art of compounding rubber and neoprene is one which involves many compromises. The most heat resistant type of rubber compound is deficient in resistance to abrasion and to mechanical fatigue. The most abrasion resistant rubber is far from the most elastic. Likewise, there is no neoprene compound that is best for all purposes although that ideal is more closely approachable in neoprene than in rubber. Hence, in a broad review such as this, it is necessary to limit oneself to a qualitative summary of the properties of neoprene compositions and of their advantages and shortcomings as compared to natural rubber.

For some industrial applications where close tolerances are involved, the dimensional change of neoprene when exposed to oils is important. If the dimensional change could be known in advance, it could frequently be compensated for in the design of the neoprene part or of the assembly in which it is used, or by pre-swelling the neoprene part in the oil that is to be encountered in service. This is not a satisfactory solution because the designer of a machine or device can seldom know exactly what oil the neoprene will be called upon to resist. Lubricants and petroleum derivatives in general are sold and specified on the basis of their physical properties but it is their chemical rather than physical properties that determine the effect upon neoprene or other elastic materials.

Practically all oils, whether animal, vegetable or mineral, cause neoprene to swell to some extent and this swelling is almost always greater at elevated temperatures than at room temperature but there is no constant relationship between the amount of swelling at one temperature and at another. When neoprene is immersed in any oil it increases in volume for a few hours or for a few days until it is substantially saturated. From that point on little change in volume is observed over a period of years.

Pure vulcanized neoprene will not contaminate or alter the properties of solvents, refrigerants or other materials with which it may come into contact. However, most commercial neoprene compounds contain added ingredients which may be extracted by solvents. Solvents that come in contact with a neoprene compound may extract the soluble constituents of carbon black that it contains and may also extract plasticizers, antioxidents and other soluble compounding ingredients. The contamination of solvents, etc., by neoprene is frequently more serious than the effect of the solvent on the neoprene itself but this is fortunately a problem that is easily overcome since, if the manufacturer of a neoprene product is fully aware of the service requirements, he is generally able to avoid including any harmful ingredients in the composition.

Continued exposure of neoprene to moderate degrees of heat, say 100 deg. C., causes it to harden slowly and lose its resilience. In spite of this shortcoming, neoprene is widely used as a replacement for rubber where high temperatures are involved because rubber deteriorates even more rapidly and its deterioration is of a type that is more objectionable.

One of the most important uses of neoprene from the chemical engineer's point of view is for lining tanks, reaction vessels, etc. The heat resistance of neoprene is much more frequently responsible for its choice as a tank lining material than its resistance to chemicals. Not only is neoprene more heat resistant than rubber, but also the adhesives that are used for bonding neoprene to metals are less thermoplastic than those commonly used for bonding rubber. For example, the hot end of a 32-foot long rocker type crystallizer was neoprene covered over three years ago and it has been in continuous service since then at a hot end temperature ranging from 180 deg. to 205 deg. F. The cold end of the crystallizer is rubber lined. Previous experience has shown rubber lining to be quite impractical at the hot end. Neoprene has also been successfully used for coating an exhaust fan handling hot acidic vapors at a temperature of 200 deg. to 220 deg. F.

To recite all of the demonstrated commercial uses of neoprene in the chemical industries would require far too much space. In the plants of the firm with which the author is connected neoprene is being used for a conveyor belt handling hot sodium silicate sinter; for ball mill port gaskets, drum sealing gaskets, etc.; as a lining for hydrofluoric acid drums; and as a resilient covering for rolls used in various coating operations. Neoprene jacketed cable is used for driving rayon spinning motors, the cable being spliced into the motor before impregnating with Bakelite varnish. Neoprene was chosen for this use because of its ability to withstand the heat of baking the Bakelite and also because the cable is exposed to acid spillage.

Electroplating tank lined with three-ply rubber

In addition to these specialized uses for neoprene, we find many uses for neoprene lined hose to handle oils, solvents and gases such as chlorine which readily attack rubber. Neoprene bonded fabric power transmission belts are used in the presence of acid fumes and fog which rapidly deteriorate rubber belts, and neoprene gloves, aprons and coveralls are worn by workers who require its protection. Neoprene soled shoes are also worn by operators working on oily floors.

Neoprene, like rubber, has its limitations. Aromatic hydrocarbons, chlorinated solvents and acetic acid all cause pronounced swelling and deterioration in physical properties. Nevertheless, neoprene is frequently used in contact with these materials for such purposes as gaskets where it is mechanically restrained from swelling or where deterioration in tensile strength, tear resistance, etc., does not make it unserviceable. Although more heat resistant than rubber, neoprene is still far short of the ideal in this respect. Since the properties of neoprene differ only in degree from those of natural rubber, one cannot assert with confidence that it will perform satisfactorily where rubber has failed due to heat or attack by oils and chemicals. The many cases in which it has solved troublesome engineering problems indicate that it is well worthy of a service trail wherever a flexible, elastic and chemically relatively inert construction material is needed.

Koroseal

Koroseal as an engineering material was the subject of the paper by F. K. Schoenfeld of the B. F. Goodrich Co., Akron, Ohio. The generic term Koroseal refers to a broad class of products with properties varying from those of hard rubber to those of a gelled rubber cement. All of these products embody substantially insoluble polymers of vinyl halides combined with different percentages of various plasticizers. Also, Koroseal may be compounded with a variety of other ingredients for specialized uses.

The harder types of Koroseal are resistant to practically all materials except: 1) organic compounds containing nitro or chlorine groups; 2) aliphatic or aromatic ketones; 3) aromatic amino compounds; 4) lacquer solvents; 5) acetic anhydride.

The softer grades of this material have, of course, the same limitations, and in addition certain oils, gasoline and benzol extract a portion of the plasticizer. By correct compounding, and proper choice of plasticizer for the particular corrosive to be resisted, the Koroseal compound can be much improved.

Recent applications of Koroseal of special interest to chemical engineers include soil corrosion of pipe lines. There are numerous so-called "hot spots" where soil conditions are such that pipe fails in a few months to a few years. To protect pipe in such services a method of covering pipe lines has been developed. The procedure is to spiral upon the pipe a cotton tape thoroughly impregnated with the compound, and then to paint this covering with a solution of the same material. Pipe thus protected has suffered no corrosion after three years' service in spots where normal pipe life is less than six months.

Koroseal tubing has been used successfully to handle chlorine gas, ozone, sulphur chloride and hydrochloric acid in chemical plant installations. The harder forms of tubing or pipe can be threaded for joining, or a slip joint, lubricated with plasticizer or solvent, then heat sealed, is practical.

Several applications have been made of Koroseal where resistance to the diffusion of gases is desired. For vacuum technique, Koroseal offers gaskets and tubing which are flexible and unchanging with age. A test reported in recent literature shows Koroseal to be superior to rubber in rate of gas diffusion.

Material	*Inside Diam.*	*Wall Thickness*	*Rate of Leak*
Koroseal tubing	$\frac{1}{16}$ in.	$\frac{1}{8}$ in.	0.060 micron/min./in.
Rubber tubing	$\frac{1}{4}$ in.	$\frac{1}{16}$ in.	0.150 micron/min./in.

A special transparent Koroseal has been made into gas masks. Tests for mustard gas penetration show the material to be superior to the best rubber compounds.

One type of rubber coated balloon cloth is made by spreading the cloth with about 40 coats of rubber cement, plying three of the spread fabrics together and curing. This cloth must pass a diffusion test with hydrogen at 70 deg. F. of not more than 0.45 cu.ft. per sq.yd. per 24 hr. Tests on coated fabrics show them to be many times more resistant to hydrogen gas diffusion than are rubber coated fabrics.

The chemical inertness suggested its use for lining metal tanks to protect them against the action of corrosive chemical solutions. Koroseal has served successfully in unusual service for which rubber is unsuited. Mixtures of nitric and hydrofluoric acids used for cleaning stainless steel quickly destroy rubber but have no effort on this vinyl compound. This chemical stability has made it valuable for insulating the racks on which articles to be electroplated are hung in the plating baths. Thin coatings successfully withstand the action of even chromic acid used in chromium plating baths.

Several methods are used to protect vessels with this synthetic rubber. In certain uses, such as the outside of pickling tanks and covers for such tanks, it has been found sufficient to use painted or sprayed coats of Koroseal cements. For more severe service, sheet Koroseal is bonded to the metal or an impregnated fabric is adhered to the metal and then covered with several coats of Koroseal from solution.

Plioweld

The advantages of rubber-lined steel equipment have been made available to the chemical engineer through the use of Plioweld and similar adhesives to unite rubber and metal, according to N. E. Kimball and F. H. Manchester of the Goodyear Tire & Rubber Co., Akron, Ohio. The utilization of rubber-lined chemical equipment meets many of the corrosion problems of the industry by satisfying requirements of

1) Chemical resistance: Rubber properly compounded, resists inorganic acids that are most difficult to handle in other types of construction.

2) Low first cost and maintenance: The cost of rubber-lined equipment is low in relation to expensive metals and alloys of equal resistance. Maintenance is practically nothing save painting and inspection.

3) Sturdiness of construction: Rubber-lined equipment can be used for transportation and resists all the exterior strains that would occur. Inside sheathing of wood or brick will protect against hazards of damage directly to the rubber.

4) Temperature limitations: Although rubber-lined equipment cannot be exposed to temperatures over 175 deg. F., it can be protected by inside sheathing of brick.

5) Safety: Rubber lining protects equipment and men against sudden ruptures as corrosion cannot weaken the steel equipment in any large area.

Continued

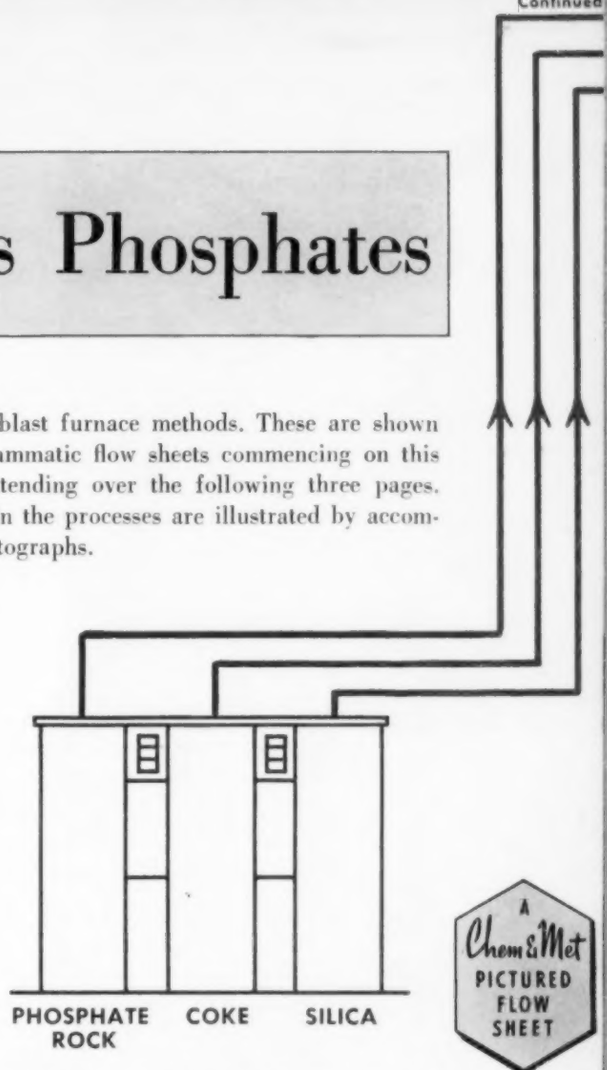
How Victor Makes its Phosphates

PHOSPHORIC ACID and phosphates may be made by either the wet or pyrolytic method. A large part of the annual production of these materials is still made by the action of sulphuric acid on ground phosphate rock or bone ash. The use of the blast furnace was first advocated in 1868 but this method did not prove economically attractive at the time. Between 1917 and 1923 the U. S. Department of Agriculture made investigations on the volatilization of phosphorus and the production of phosphoric acid for concentrated phosphate fertilizers. Several types of oil-fired furnaces were constructed and operated experimentally for short periods with promising results. However, there was no commercial development of the fuel-fired furnace for phosphoric acid until 1924, when the Victor Chemical Works began a study of this method. A small furnace was built at the company's Chicago Heights plant in the early part of the year. This work led to the construction of a large fuel-fired furnace five years later at the Nashville, Tenn., plant. Upon completion of this furnace the sulphuric acid or wet process was abandoned by this company and the blast furnace, except for interruptions necessary for repairing, has been in continuous operation ever since that time.

The gaseous products of combustion from the furnaces, containing the P_2O_5, are led into hydrating chambers where they are cooled and hydrated. These cooled gases are then drawn through a series of draft fans and distributed to the Cottrell precipitators where condensation of the phosphoric acid takes place. The acid condensed in these units ranges in strength from 85 to 90 per cent ortho phosphoric acid, and has only to be diluted, treated for arsenic and filtered before it is ready for the market, or for use in making phosphatic salts or compounds.

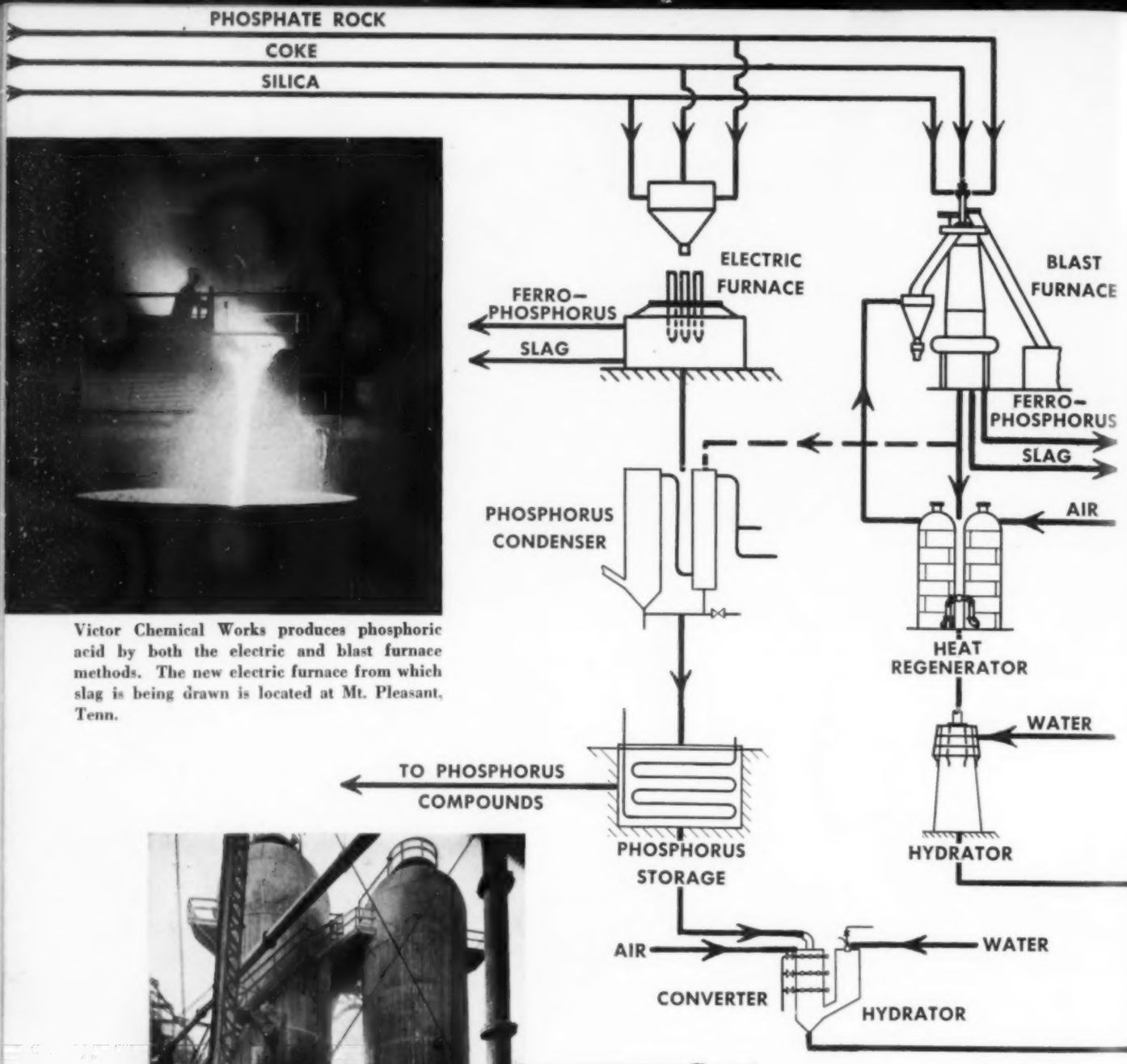
In recent years the Tennessee Valley Authority has done much to stimulate interest in the use of the electric furnace for the production of elemental phosphorus, phosphoric acid and phosphates. Reports of this extensive investigation have appeared in a series of articles in *Chem. & Met.*, during the past four years.

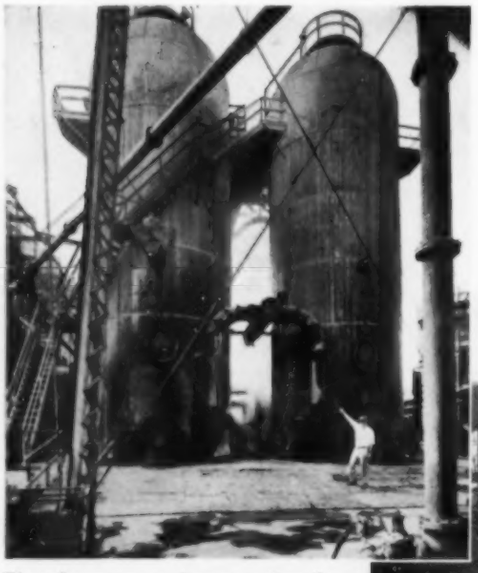
An electric furnace of modern design was completed and put in operation in June, 1938, at its Mt. Pleasant, Tenn., plant by the Victor Chemical Works. The installation of this furnace places Victor in the unique position of producing these chemicals by both the electric and blast furnace methods. These are shown in the diagrammatic flow sheets commencing on this page and extending over the following three pages. Many steps in the processes are illustrated by accompanying photographs.



The raw materials, phosphate rock, sand and coke, from which phosphoric acid and phosphates are produced, are stored in great concrete silos

Victor Chemical Works produces phosphoric acid by both the electric and blast furnace methods. The new electric furnace from which slag is being drawn is located at Mt. Pleasant, Tenn.

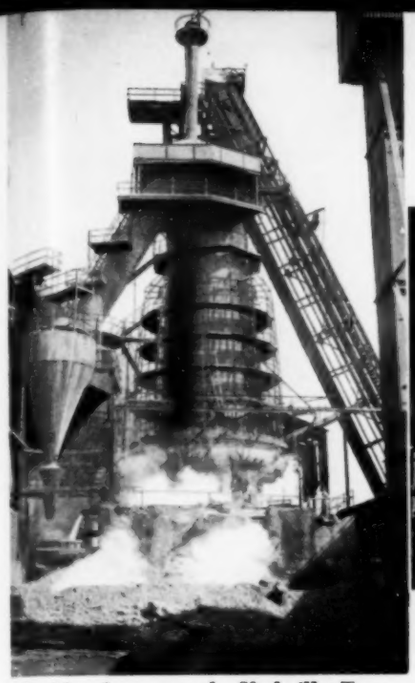




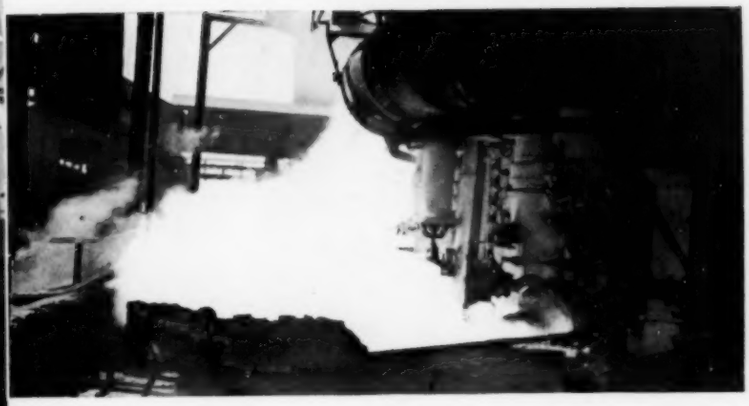
Phosphorus vapor is proportioned with air, and oxidized to phosphoric anhydride in heat regenerators which preheat the air for the blast furnace

Mains for conducting the oxidized gases from the heat regenerators to spray towers for cooling and hydrating the phosphoric anhydride

The spray tower or hydrator in which water is added to the anhydride in order to cool and to hydrate it in the process of making phosphoric acid

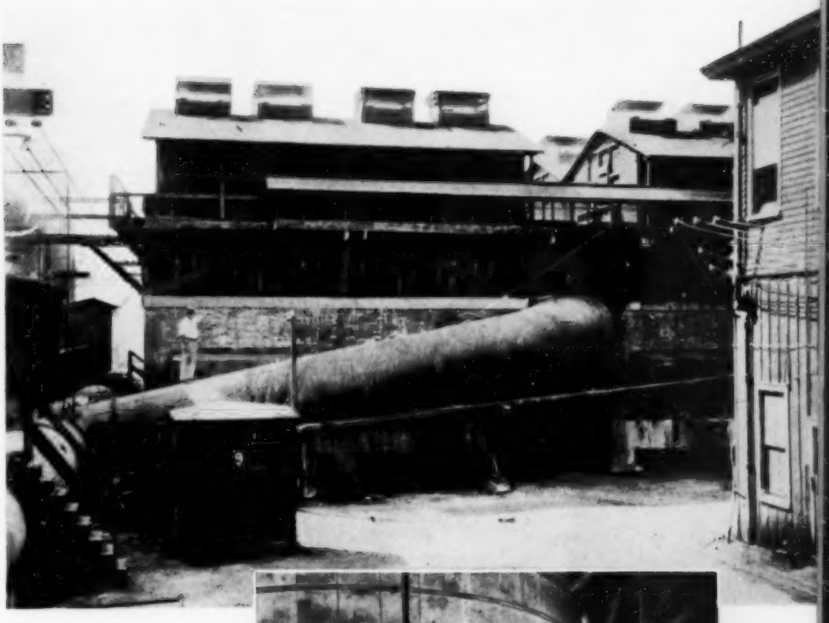


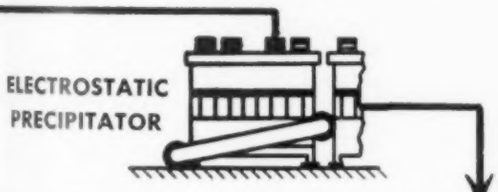
The blast furnace at the Nashville, Tenn., plant of Victor Chemical Works. An electrically driven scale car and bell-bottom buckets are used to collect and carry the raw materials up the skipway and to dump them into the furnace



The ferrophosphorus formed from the iron impurities in the rock and coke and the slag are tapped from the furnace hearth. The former may be converted into phosphates by special processes

Gaseous products of combustion from the blast furnaces, after being cooled and hydrated, are then drawn through a series of draft fans and distributed to the Cottrell electrical precipitators where condensation of the liquid acid takes place

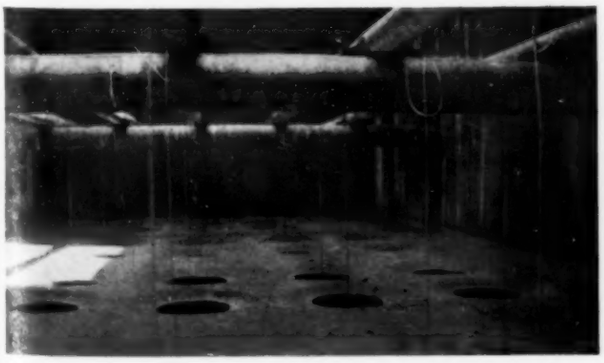


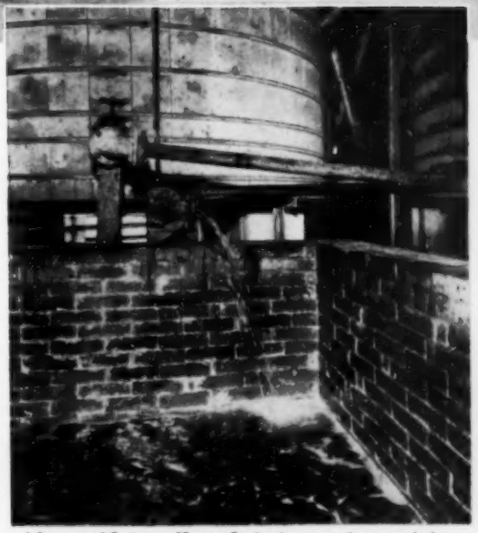


PHOSPHORIC ACID

TO OTHER PHOSPHATES

Arrangement of the carbon tubes in a Cottrell unit. A high-tension electrode is suspended concentrically in each tube. Carbon is not corroded by the acids nor does it sag out of shape





After acid is collected, it is run into mixing tanks where it is checked for quality and measured. The acid is then pumped into the main pipe line distribution system to supply phosphate raw material for many compounds made therefrom

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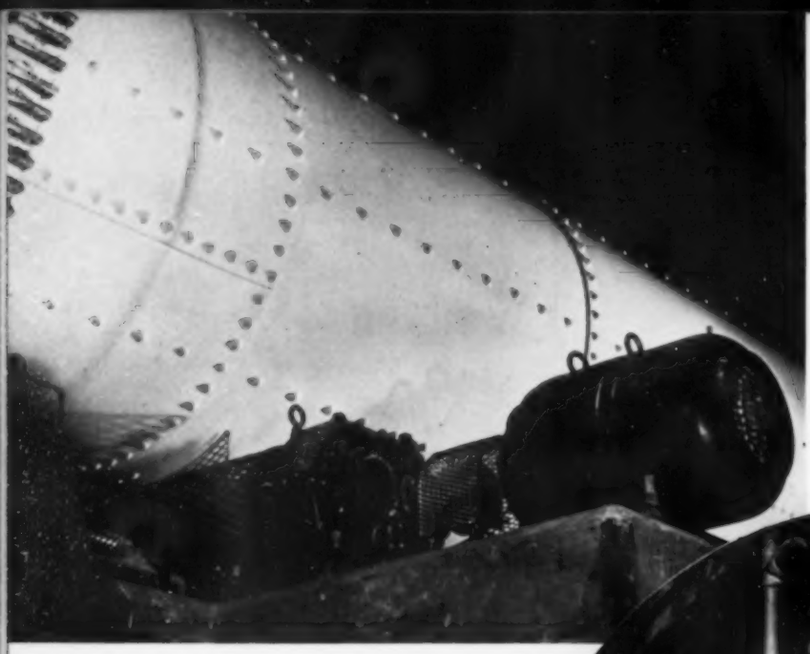
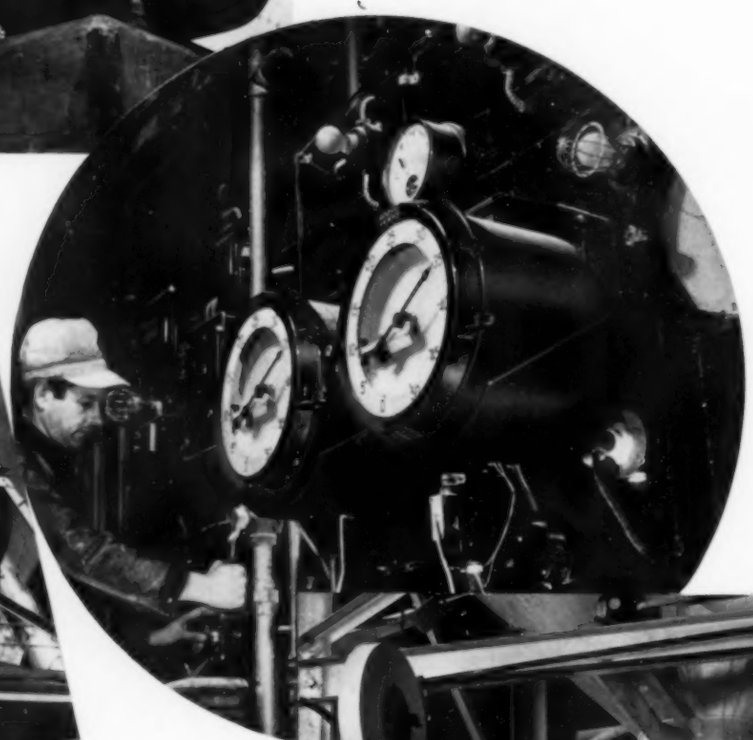


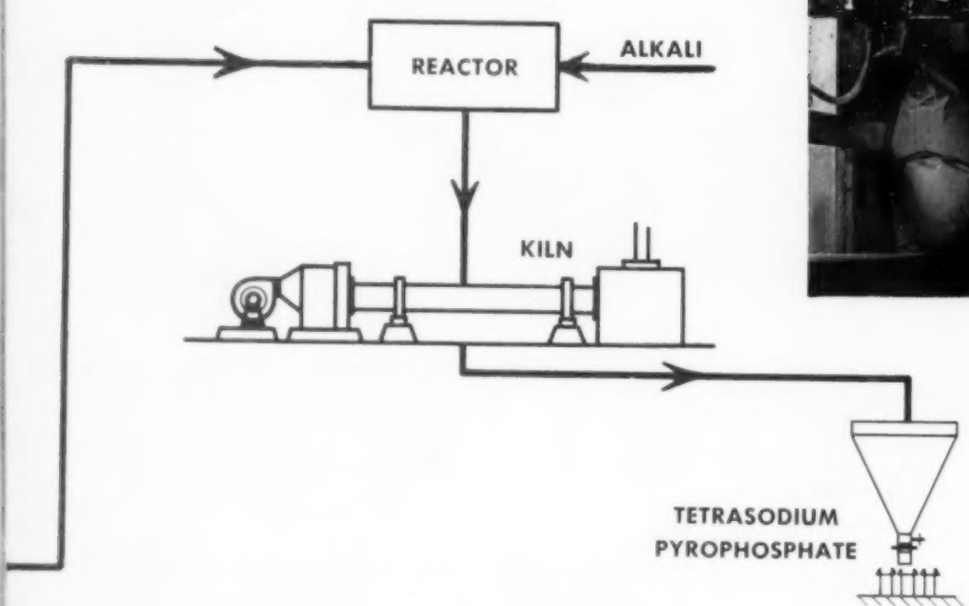
In the process of making tetrasodium pyrophosphate, phosphoric acid is caused to react with alkali to produce a solution of disodium phosphate. Automatic pH control and electric eyes are used to insure uniform and proper proportioning. The disodium phosphate solution is then dehydrated and heated using natural gas to produce the pyro salt

Various gages and temperature instruments facilitate close control of these operations



Dust from the heating operations is recovered from cyclone type collectors

The kiln product is milled and conveyed to a supply hopper from which it is weighed into containers for shipment



New Electrochemical Developments

An editorial staff report on the meeting of the Electrochemical Society at which the developments in refractories, electroplating, electrolytic cells, electro organic chemistry and corrosion of alloys were discussed. New officers were elected.

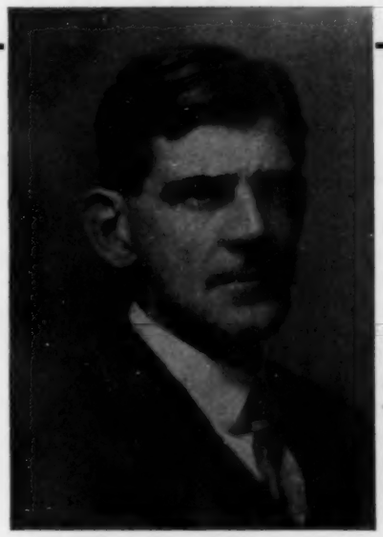
THE ANNUAL MEETING of the Electrochemical Society was held in Columbus, Ohio, April 26-29. Among the places of interest that were visited are the Battelle Memorial Institute, the Orton Memorial Institute and the Owens-Corning Fiberglas Corp.

The opening technical session was devoted to refractories in the electrochemical industry. L. J. Trostel, General Refractories Co., presided.

Electric carbonization of coal is the title of a paper delivered by H. Stevens of Cincinnati. In the electric carbonizing process, bituminous coal or lignite is heated electrically from within and the products are coke, gas and oil. Upon comparing the electric process with the old byproduct coke oven process, it is shown that construction and maintenance costs are lower for the electric process. The coke produced is of uniform burning qualities and the oil is of superior quality. The process is adaptable to off-peak electric power.

Porous carbon electrodes were discussed by George H. Heise, National Carbon Co., Cleveland. Various applications and their usefulness in electro-oxidations and reductions, both organic and inorganic, were covered. Three processes were considered in detail; electrowinning of copper, production of *p*-nitraniline, and oxidation of arsenite to arsenate with accessory air depolarization at the cathode.

New stoneware in the electrochemical field was described by Percy C. Kingsbury, General Ceramics Co., New York. Highly vitrified clay products, due to their almost complete resistance to corrosion, occupy a unique position as structural materials for electrochemical equipment. Stoneware, the most important of these ceramic bodies for chemical purposes, is fabricated into every kind of industrial equipment and is available in shapes weighing up to a ton or more.



Dr. H. Jermain Creighton, newly elected president of the Electrochemical Society

New vice presidents are: D. A. Pritchard of Montreal, Alexander Lowy of Pittsburgh and J. D. Edwards of Pittsburgh. The new managers are: C. E. Williams of Columbus, K. G. Soderberg of Detroit and James A. Lee of New York. R. M. Burns and Colin G. Fink were reelected treasurer and secretary, respectively.

Dr. Francis C. Frary was selected to receive the Edward Goodrich Acheson medal and $1000 prize. The award will be made in September. He is director of research for the Aluminum Co. of America.

W. P. Ruemmler of St. Louis was awarded the Weston Fellowship of $1,000. And N. B. Nichols of Ann Arbor, Mich., was awarded the Society's prize to young authors.

In his paper on the relation of low weight to the physical properties of furnace refractories, C. L. Norton, Jr., The Babcock & Wilcox Co., New York, discussed the weight and porosity of insulating firebrick in relation to their thermal conductivity, heat capacity, spalling, cold crushing strength, hot load bearing capacity, permeability and resistance to slag erosion and abrasion.

Refractories of the alumina-silica series was the subject of a paper by Fred A. Harvey, Harbison-Walker Refractories Co., Pittsburgh. And the physico-chemical control of properties of clays was discussed by John D. Sullivan, Battelle Memorial Institute.

Electroplating and electrolytic cells were the subjects of the second technical session. Prof. E. M. Baker of the University of Michigan presided. Plating on aluminum was discussed by W. J. Travers, Krome-Alume, Inc., Lockport, N. Y. In ordinary electroplating on aluminum, the adhesion of the plate is poor. To ensure perfect contact, the aluminum surface is accordingly submitted to a new process. The first step comprises an electrolytic anodizing treatment, with alternating current in an aqueous bath containing 30 g./L. of oxalic acid. Ten minutes at 50 volts and a bath temperature of 20 deg. C. are recommended. Then follows a 13-minute treatment in a 60 g./L. solution of sodium cyanide; and after a thorough water rinse, an electrodeposit of nickel is applied employing one or the other standard nickel baths. On top of the nickel a plate of chromium, copper, iron or other metal can be applied following ordinary commercial procedure for these metals.

The mechanism of the reaction of the lead storage cell was related by Prof. M. deKay Thompson of Mass. Inst. Tech. It was shown that the mechanism of the reaction taking place in the lead storage battery can be explained by a combination of the LeBlanc theory with that of Liebenow, without involving the disappearance of ions

from the solution which do not exist there in the first place.

Electrodeposition of nickel from nickel chloride solution was presented jointly by W. A. Wesley and J. W. Carey of International Nickel Co., New York. This paper reported the results of work done in the laboratory in the successful development of a nickel plating process using a nickel chloride-boric acid solution instead of the conventional sulphate electrolyte. The new chloride bath was said to produce a deposit which is finer-grained, smoother, harder, stronger, and somewhat less ductile than ordinary nickel plating deposits. In addition to these advantages, a 50 per cent reduction in tank voltage and power consumption is permissible, control of the bath is easier, a wide plating range is achieved, and high anode and cathode efficiencies are attained. The plating is more readily buffed, has less susceptibility to pitting, and has less tendency to form nodular growths and trees on thick deposits.

Among the other subjects that were treated are: electrodeposition of silver-lead alloys for bearings by C. L. Faust and Beaumont Thomas, chemical engineers, Battelle Memorial Institute; the comportment of the palladium-hydrogen system toward alternating electric current, by George A. Moore, Princeton University; degree of hydration of the anion SO_4 derived from the electrolytic water transport, by J. Baboronsky, Czechoslovakia; electrolytic manufacture of perchloric acid from sodium chlorates, by K. C. Newman and F. C. Mathers, Tri-State College and the University of Indiana, respectively.

The symposium on electro organic chemistry was presided over by Prof. Sherlock Swann of the University of Illinois. The electrochemical reduction of sugars to their corresponding alcohols at mercury and amalgamated lead cathodes has been studied in aqueous alkaline solution in cells with an Alundum diaphragm by H. J. Creighton of Swarthmore College. Detailed results were given for the reduction of glucose, mannose and invert sugar. The effect of various factors such as current density, temperature, catholyte composition and diaphragm permeability on the yield of alcohol were discussed. It was shown that the relative amounts of sorbitol and mannitol obtained simultaneously by reducing glucose can be varied by changing the hydroxyl-ion concentration of the catholyte. In conclusion, the commercial development of the electrochemical reduction of sugars and the uses of the reduction products were discussed briefly.

Furfural has been reduced electrochemically to give a new compound, hydrofuroin, with its isomer, isohydrofuroin, W. C. Albert and Prof. Alexander Lowy of the University of Pittsburgh reported. Small amounts of furfural alcohol and some resin are also formed. The effect of various factors such as cathode material, current density, temperature and pH of the catholyte has been studied, and optimum conditions for obtaining yields of hydrofuroins up to 63 per cent were described.

The electrolytic formation of the azo dyes, roccelin, orange II, congo red, Bismarck brown, and chrysamine G at platinum or nickel anodes in a divided cell with an anolyte containing the requisite organic compounds in the sodium nitrite solutions was reported by C. J. Brockman and J. W. Griffin, Jr., of the University of Georgia. The variables were temperature, current density and ampere hours. The use of a saturated aqueous solution of the hydrotropic salt, sodium xylenesulphonate, as the solvent in the anolyte was also reported; the yield of chrysamine G was better in the presence of this solvent.

The electrolytic reduction of benzoic acid to benzyl alcohol has been studied at cathodes of cadmium, tin, lead, mercury, zinc, aluminum, nickel, copper and iron by Prof. Swann and G. D. Lucker of the University of Illinois. Appreciable yields of benzyl alcohol were obtained only at cathodes of lead and cadmium. The influence of the physical condition of the surface of the cathode was discussed. The best yield of benzyl alcohol was 85 per cent obtained at an extruded 99.99+ per cent lead cathode. The conditions described by Mettler were recommended. An aqueous alcoholic catholyte was used in place of the alcoholic catholyte. The current was 5 amp. For long runs a 40 per cent acid is recommended.

Several other papers were presented. Fr. Fichter of Basle University, Switzerland, had a paper on electrochemical experiments with various organic acids. S. Glasstone and A. Hickling, The University of Sheffield, England, and University College, Leicester, England, reported on the mechanism of the kolbe electrosynthesis and allied reactions. C. L. Wilson of University College, London, reported on analogies between electrolytic and chemical methods of reduction. W. E. Bradt and A. W. Erickson of the State College of Washington, had a paper on the electrochemical reduction in acid solution of paranitrophenetole. Prof. O. W. Brown and Alice E. Brown of Indiana University contributed a paper on the electrolytic preparation of 2, 4-dinitrobenzoic acid from 2,4-dinitrotoluene.

The final session was on the corrosion of alloys. Prof. F. R. Morral of Purdue University presided. The rate of anodic solution of 12 metals and 56 alloys has been studied and tabulated by Professors Morral and J. L. Bray of Purdue University. The electrolyte was a solution containing 15 to 20 per cent, by weight, of sulphuric acid. The rate of solution of a lead alloy containing 0.005 per cent of tellurium was only 1/10 that of commercial lead. Its alloys containing 14 per cent of silicon and iron alloys containing 25 per cent of titanium have respectively 1/20 and 1/10 the rate of corrosion of iron. It is believed the silicon forms an anode surface film which increases with time and current. This film is, however, brittle. The anodic behavior of chromium steels and stainless steels, nickel alloys, carbides, high-speed steels, and others, has also been investigated.

The dezincification of alpha brass with special reference to arsenic was the subject of a paper by Frederick W. Fink, Battelle Memorial Institute, Columbus.

When metals are applied as protective coatings by electrolysis or other methods, preferred orientations are often developed, according to Gerhard Derge of Carnegie Institute of Technology.

The alloys of indium and tin were investigated throughout the entire range by Prof. Colin G. Fink, Prof. E. R. Jette, S. Katz and F. J. Schnettler of Columbia University. Thermal and x-ray methods were used. Indium is only slightly soluble in tin (about 1.5 per cent In), but tin has a considerable solubility in indium (about 10 per cent Sn). Two compounds were detected, one with about 10 per cent In, the other with about 75 per cent In. In general, all of the alloys were soft and ductile, with a relatively high fatigue resistance. Corrosion tests in 3 per cent brine solution and in saturated oxalic acid solution show that the addition of either metal to the other markedly increases the corrosion resistance.

Training Employees in Management

Two methods for the upbuilding of employees have figured extensively in the continued success of Abbott Laboratories. They are committee management and study club activities, both of which were initiated by employees.

PUBLIC RELATIONS for CHEMICAL PROCESS INDUSTRIES

H. E. FLEMING
Business Research Corp.
Chicago, Ill.
Based on an interview with
S. DeWITT CLOUGH
President and General Manager
Abbott Laboratories
North Chicago, Ill.

S. DeWitt Clough

"ACCORDING TO the financial pages, Mr. Clough, the Abbott Laboratories has continued to pay dividends to its stockholders year in and year out despite the many ups and downs of business since 1929. In addition it has built a new research building, added new products, expanded its business and increased its force of employees. Surely this indicates that you have some personnel and public relations policies that make for harmony and efficiency on the part of the employees of your company."

This was the start of an interesting and illuminating interview with S. DeWitt Clough, president and general manager of Abbott Laboratories, manufacturing pharmaceutical chemists, at his office in one of the 19 buildings at the headquarters plant of this company.

There are two outstanding features of the policies developed by Abbott Laboratories in the last six or seven years about which Mr. Clough is most enthusiastic and which to the writer appear to be the most significant. These are:

1. Committee or group management—A system involving some twenty committees and a board of directors, each made up of first, second and third-line executives and supervisors. In many cases the committees are supplemented with sub-committees of non-supervisory employees.

2. The Abbott study club—An employee organization, initiated on petition from stockroom and shipping employees, which in the seven years from 1932 to 1938 inclusive, has conducted 24 courses on a wide range of subjects involved in the business. It has held 325 meetings with total enrollments of 1,331 and total attendance of 21,204.

These two policies have one notable characteristic in common. This is that they provide a great stimulus for the ambition of all employees desiring, in an expanding business, to grow and advance in the organization on the basis of acquired qualifications.

"One policy which we try to follow closely is what I choose to call the group management or committee management policy," said Mr. Clough. "Abbott Laboratories is not a one-man organization. In fact it is far removed from the old idea which held sway some thirty years ago in business and which has since reappeared in political and economic life.

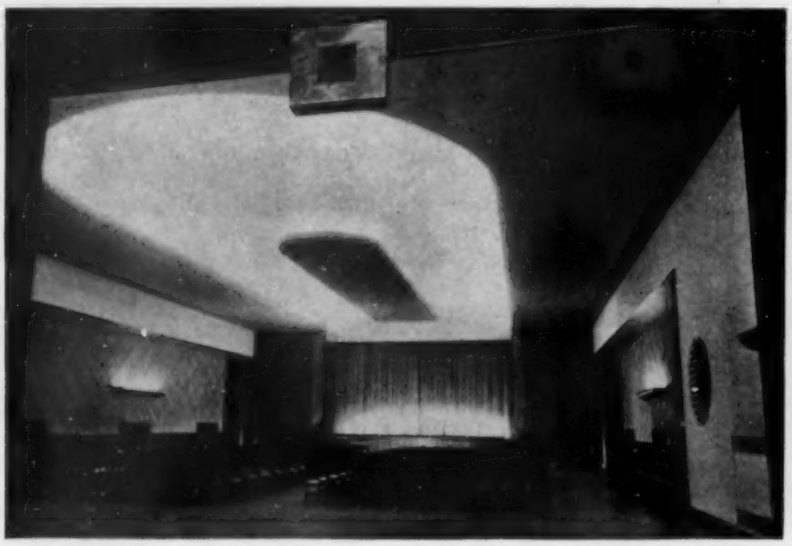
"The three top men in the Abbott organization could retire tomorrow and this business would go right along without interruption or outside replacements. We have worked hard to build up second and third lines of defense in every department of the business and have been fortunate in securing a fine lot of material in the way of able young men to work with. Thus the management of this business is securely insured for many years to come."

The group management plan embodies the appointment of a personnel manager and a personnel committee, with which are associated a safety committee, supervising safety contests in the various departments and a medical committee studying working conditions and the protection of the health of employees in various classes of work. A suggestion committee considers hundreds of suggestions from employees each year and cash prizes are awarded for the best suggestions. Another committee is in charge of catalog deletions and a pricing committee keeps the price lists of the company up to date.

"Out of the practice of the officers in inviting conference with employees," said Mr. Clough, "has emerged a group of committees and sub-committees, all of which are doing excellent work.

"A research and control committee had previously been appointed by Dr. Alfred S. Burdick. This committee headed by the vice-president in charge of research and control, Dr. Ernest H. Volwiler, is still holding monthly meetings. To it are referred all requests and suggestions for new products. Here also progress in new research products is discussed and changes in old products considered.

"No new product can be released by the products planning committee



An innovation in industrial plant facilities is the beautiful air-conditioned auditorium of Abbott Laboratories, manufacturing chemists. No less spectacular is the research building in which laboratories and the auditorium are housed

without a recommendation from the research and control committee, for it is this committee which supervises preliminary and routine testing for toxicity, stability, accuracy, and efficiency.

"In some cases several years of research, preliminary investigation and clinical trial are needed to determine the practical value of a new product. Frequently, large series of new clinical compounds are studied.

"The products planning committee includes representatives from the research, production, cost, pricing, advertising and sales departments. Here all details for the marketing of a new product are studied and decisions made. Assisting this committee are other groups studying packaging, production planning, distribution, sales promotion, literature and labeling.

"The top committee is the executive committee, headed by Mr. R. M. Cain, executive vice-president. Recommendations of the executive committee are passed on to the board of directors. This board, headed by the chairman, Mr. E. H. Ravenscroft, is unique in that it consists of 15 Abbott employees, all of whom are available on very short notice.

"The board of directors, on which are represented all branches of the business, lunch together each day and discuss business problems as well as matters of mutual interest. The board of directors is assisted by the budget committee, the finance committee, production planning, the legislative committee, and a recently organized research coordination committee."

Questioned as to the problem of getting action out of a committee, Mr. Clough said:

"This method of management may appear at first to be cumbersome, but it has its advantages and, believe it or not, the system works here. Of course, we have had to train, and are still training, these committees and those presiding over them, to operate as smoothly and quickly as possible without too much superfluous or time-consuming discussion. The idea is to try to reach conclusions without permitting discussions to go on detours or up blind alleys. By sticking to a straight line, tactful handling, and reasonable speed, the chairmen of committees can accomplish a great deal without friction or delay.

"Careful minutes of all committee meetings are kept. Recommendations are made by the committees and approved or disapproved by the executives or the executive committee."

Then Mr. Clough made one of the key points, saying:

"A large number of our young men are trained on these committees for future executive positions. They appreciate the opportunity and the responsibility."

The principle of consulting those concerned before taking action affecting them is running through modern management, especially in efforts to improve the internal and external relations of business corporations. In describing the Abbott committee man-

Statistical Picture of Seven Years of Training Classes Initiated at Request of Plant Employees

Year	Courses	Number of meetings	Total attendance
1932	Sales training	48	960
1933 (Spring)	Sales training	10	220
1933 (Fall)	The Importance of Plant and Office Procedures	15	750
1934 (Spring)	Abbott Departmental Study (Tour of plant, etc.)	15	795
1934 (Fall)	A Theoretical Product Traced Through All Stages	15	900
1935 (Spring)	Contemporary Thought Lecture Series	15	1,050
1935 (Fall)	J. Manley Phelps "Better English"	11	1,023
1936 (Spring)	Public Speaking	10	220
	Shorthand	10	130
	Chemistry	10	250
	Pharmacy	10	120
	Dept. Functions	10	600
	Two dinner meetings	.....	319
1936 (Fall)	Letter writing	13	260
	Spanish	13	195
	Better English	13	130
	Abbott Products	13	520
	German	13	78
	Dinner meeting	.....	170
1937 (Spring)	Spanish	15	150
	Letter Writing	15	450
	German	15	75
	4 special meetings	.....	280
	Dinner meeting	.....	178
1937 (Fall)	Psychology "Dr. Crane's Treasure Hunt"	11	2,618
1938 (Spring)	Variety Programs (Talent Night with 1,009 present)	14	3,465
1938 (Spring and Fall)	"Information Please"	27	2,790
	Pharmacy, Accounting and Home Nursing	.....	85
	Number of guest tickets 10 regular meetings	.....	660
	1 evening meeting	.....	550
Total enrollments			1,331
Number of meetings			325
Average attendance			122
Total attendance			21,204

agement system further, Mr. Clough said:

"The most annoying thing in business is to have one or two men make a decision without consulting with others who are directly or indirectly concerned. We have eliminated to a large extent this danger with our group management plan, but of course, as in any large concern there are occasional slips which serve only to emphasize the importance and wisdom of group action as compared with uncoordinated and half-baked action.

"A similar method is being used in the sales department for the training of sales executives. Branch and district managers' meetings, organized by the vice-president in charge of sales, Mr. R. E. Horn, and his assistants, are frequently held, as well as district sales meetings and general sectional sales conventions twice a year.

"Six years of successful experience has proved the value of this committee management policy. It is a policy, however, which calls for constant supervision, active follow-up, careful planning, and close cooperation."

All told there are about 1,500 employees in the Abbott organization, including those in the offices, laboratories, and other buildings at North Chicago, the manufacturing plants at Philadelphia, Montreal, Mexico City, and London, England, and the thirteen branches in the United States, as well as sales offices elsewhere. Of the total, 700 to 800 work at North Chicago. Since there are some 1,000 products in the Abbott line, both standard pharmaceuticals and specialties, many of the latter having been developed largely by the Company's research, the employees in the stockroom and the shipping department naturally have their thoughts carried to the world outside of the plant gates.

It was seven years ago that twelve young men in the stockroom and shipping departments petitioned the president of the company to organize a salesmen's training class for employees in the plant. Their object, as they put it, was that by this means they might be given an opportunity to get on the sales force.

Such a class was started, and Mr. Clough, in telling about it, said that two employees of this original group are now assistant branch managers. The class was continued for several years, but later the idea behind it expanded. The experience led to the establishment of a study club, organized to give a larger number of employees opportunities for special courses and lecture classes. A statistical picture of seven years of these activities is presented in the table on the opposite page.

An employees' tour of the plant in connection with a study of its departments, the tracing of a theoretical product through all stages, intensive consideration of plant and office procedures, as well as studies of chemistry, pharmacy, and the line of Abbott products, have been some of the features of the practical courses of the study club. For the office workers there have also been courses in shorthand, letter writing and "better English."

The study club committee changes from year to year, but is guided by the experience of past presidents of the club, as well as by the new officers elected by the members.

Under the classification of general Abbott personnel activities are the Symphony Orchestra, the Choral Society, the Dramatic Club, and interdepartmental bowling, softball and basketball teams. These activities include the girls as well as the men. Dances, minstrel shows, amateur talent nights, musical nights, picnics and other employee activities are handled by the personnel committee and sub-committees of employees.

The splendid Abbott auditorium, designed by Raymond Loewy and seating 900 persons, lends itself to many employee events. This auditorium is air-conditioned and equipped with a modern stage, dressing rooms, projection room, public address system, spacious lobby and checking facilities. "Employee group life insurance, group accident and health, group hospitalization and group savings plans are in operation," said Mr. Clough. "Individual employees may make favorable arrangement with Mr. J. F. Stiles, Jr., vice-president and treasurer of Abbott Laboratories for home building, stock ownership, or personal loans. Pensions are in effect and retirements are arranged on a graduated scale, depending upon the age, length of service, merit and salaries of employees."

Abbott employees are provided with health examinations, skilled first aid and excellent food at less than cost. Hobby clubs, social gatherings, musical societies, athletic contests, insurance, etc., also figure in the employee relations program

Process Equipment NEWS

Machinery, Materials and Products

Improved Classifier

SEVERAL IMPROVEMENTS in design are apparent in the new Hydro-Classifier recently announced by the Hardinge Co., York, Pa. The driving head embodies a geared-head motor and a cast iron housing in which a cut-tooth gear rotates on ball bearings in oil. The use of a spur gear drive permits forcing the scraper through heavy solids should they pack in the bottom of the tank. In order to avoid carrying fines out with the coarse discharge, the central discharge opening in the bottom of the tank is surrounded by a swirling vortex of water to assure clean oversize. The new classifier is made in standard steel or in special acid-proof construction. Special metals, rubber-covered metal, or wood may be used where necessary.

This company has also announced an improvement in its scraper mechanism for thickeners. The "Auto-Raise" mechanism, designed to prevent damage to the thickener parts in case of overload, employs a driving sleeve with slots set at an angle to drive a yoke attached to the scraper shaft. When resistance against the shaft increases above a predetermined amount, the yoke "walks up hill" until the resistance is relieved. There it stays until the condition is rectified when it backs down to its proper position.

Automatic pH Instrument

DEVELOPED for use in all manufacturing operations where large scale pH control must be accurately maintained, a new automatic pH instrument has recently been announced by the National Technical Laboratories, Pasadena, Calif. The new instrument incorporates a potentiometric circuit that is automatically maintained in null balance by a 110 volt a.c. electronic amplifier. The device can be plugged into any standard light circuit and is designed for automatic compensation of voltage fluctuations. A Beckman glass electrode is used as the primary instrument. Provision is made for connecting additional indicating meters at any distance from the instrument and for connecting a controller mechanism and any standard recording potentiometer. The instrument itself gives a continuous pH indication on a 6-in. direct reading scale. One important feature is automatic temperature compensation by means of a resistance thermometer incorporated in the electrode assembly, which automatically adjusts the instrument for any change in temperature of the test solution. Beckman automatic pH instruments are available in standard scale ranges of 0-7 pH, 3-10 pH, or 6-13 pH in 0.1 divisions, and in other scales and ranges on special order.

Automatic Molding Press

COMPLETELY AUTOMATIC operation of a 50-ton molding press for phenol-formaldehyde and similar plastics has been announced by the Standard Machinery Co., Mystic, Conn. The new press will shortly be installed at the plant of the Bridgeport Moulded Products Co., Bridgeport, Conn., and can there be inspected in operation.

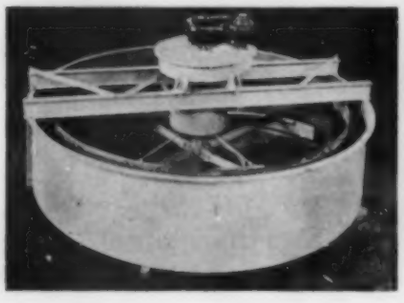
Equipped with a multiple-cam Bristol cycle controller the new press automatically performs all the operations of routine molding including feeding the molding powder into the cavities, closing the press, opening it slightly for gassing, closing again to complete the curing process, opening it, ejecting the finished molded parts, removing the flash, and repeating the cycle. In tests with a 28-cavity mold for extension cord caps, the press has operated continuously on a 55-second cycle which included 13 seconds for the opening and closing of the press, and 7 seconds for gassing. Less than 30 seconds is actually required for the press cycle, although additional time is needed, of course, for curing.

A combination of hydraulic and pneumatic operation is employed. The press itself is a modification of this company's standard toggle-operated hydraulic molding press (*Chem. & Met.*, Aug. 1936, p. 446) which is of the self-contained type, using a two-stage Vickers pressure pump operating at 200 and 800 lb. per sq. in. pressure. The die plates of the press may be heated either electrically or by steam. Push button control may be substituted for automatic control for testing. Presses for greater capacities will be built if desired.

Inclined-Grate Cooler

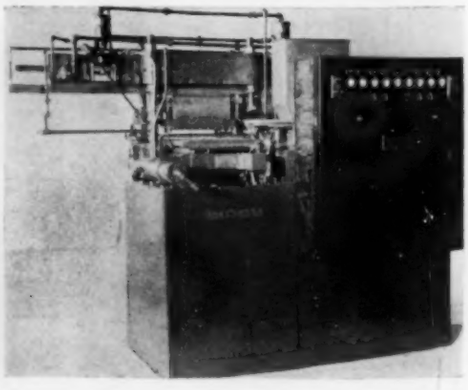
ROUGHLY SIMILAR in appearance to an inclined-grate stoker, a new cement-clinker cooler recently announced by the Fuller Co., Catasauqua, Pa., is said to

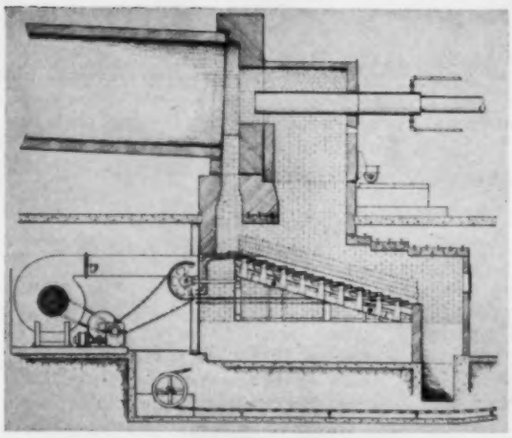
Improved classifier design

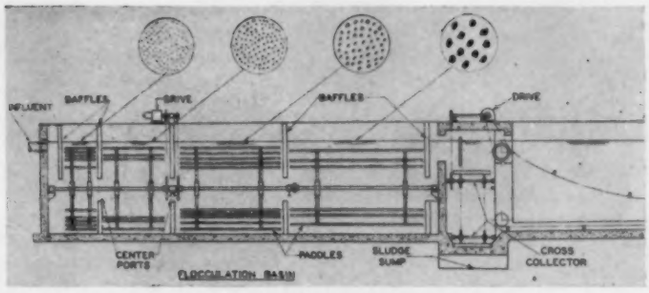


Potentiometric pH indicator

New Standard fully automatic molding press







New Floctrol flocculation equipment

Left—Cross section of inclined-grate clinker cooler

Left Below—Improved vacuum mixer

be unique in mechanical simplicity and in small space requirements. The primary cooler comprises essentially a brick chamber below and either in line with or at right angles to the kiln. Clinker drops upon grates where it forms a substantially flat, inclined bed, moved at a uniform rate to the discharge. The grates are water cooled to protect the metal. Fixed grates alternate with reciprocating grates. Beneath the grate is a wind box, the cooling air from which is forced through a large number of flared openings in each grate. The heated air rises directly from the clinker bed to a preliminary combustion chamber where it surrounds the fuel nozzle and enters the kiln with the fuel stream. A secondary cooler may be combined with the primary cooler, although separate primary and secondary cooler installations are generally recommended. Construction similar to the primary is employed for the secondary cooler.

Improved Vacuum Mixer

A NEW DESIGN of vacuum mixer which has but one packing gland has been announced by the Read Machinery Co., York, Pa. Used on plastic compounds, inks, paints, and various resin compounds under full vacuum, the new mixer evaporates moisture or solvents at temperatures considerably below their boiling points. The single packing gland feature is said to eliminate all possibility of lubricant contamination of the mix since sealed vacuum chambers are provided on the bowl ends to isolate oil or grease which might be pushed out of the shaft bearings. Various mechanical features are included. Among these may be mentioned a one-shot grease lubrication system for all bearings, with visible indicators; silent chain drive with herringbone intermediate gears; Timken roller bearings; counter-balanced cover; and heavy-duty power dump. Sight glasses on both chambers and the gear box permit continual inspection at these points. Either naben or sigma type agitators may be supplied, as desired, and the parts in contact with the mix may be constructed of either ferrous or nonferrous alloys.

Fire Hose Nozzle

DESIGNED for extinguishing all classes of fires, a new type of hose nozzle for general use on fire hose lines has been announced by American-LaFrance-Foamite Corp., Elmira, N. Y. This device, known as the Poweron nozzle, discharges water in a form said to be especially effective for fire-fighting purposes and incapable of conducting electricity. Underwriters Laboratories' tests showed the nozzle suitable for use on equipment carrying current at voltages as high as 250,000. According to Factory Mutual Laboratories, the new nozzle is of value for fires with flash points as low as that of kerosene. Under favorable conditions, it is said to extinguish fires in even more volatile liquids. Similar in appearance to an ordinary fire hose nozzle, the Poweron is non-adjustable so as to prevent possible formation of either a solid stream or an ineffective spray.

Flocculation Process

A NEW flocculation apparatus, known as the Floctrol, for the treatment of turbid waters, has been developed by the Jeffrey Mfg. Co., Columbus, Ohio. This equipment is also used for treating waste waters, for water softening and for industrial processing. The flocculation unit is a rectangular multi-compartment tank with a paddle wheel mechanism in each compartment as shown in the accompanying illustration. Placement of the openings between compartments at the center of agitation is said to eliminate short circuiting. With this system a theoretical detention time of 30 min. is reported to be ample for complete coagulation and flocculation. The time required for each stage of treatment varies, the first having the paddle wheel with the largest number of blades and the shortest detention time and each succeeding compartment having a lesser number of blades and a longer detention time. Such units are furnished singly for flows of 1 to 10 m.g.d.; or in multiples, for larger plants.

Equipment Briefs

A NEW TYPE of metal spray gun which employs a gasoline blow torch as the source of heat and operates on low air pressure has been developed by the Turner Brass Works, Sycamore, Ill. Said to be suitable for use in producing coatings for fire, rust and corrosion protection, the new gun features ruggedness, simplicity, a cool spray, ready control and low operating cost.

FOR THE EMERGENCY protection of workers whose clothing may catch fire, the Mine Safety Appliances Co., Braddock, Thomas & Meade Sts., Pittsburgh, Pa., has introduced a fire blanket which is normally folded into a vertical metal case located near where a fire hazard exists. Should an accident occur, the victim thrusts an arm through a loop attached to the blanket, pulls and rotates his body so as to be completely enveloped as the blanket pulls from the case.

MODEL M. U., a new universal photoelectric reflectometer introduced by Pfaltz & Bauer, Inc., Empire State Bldg., New York City, is intended for use in the testing of sugar, starch, paper, cosmetics and other materials where the determination of minute differences of shade is important. The instrument employs a novel type of photocell with an aperture in the center through which a light beam is projected against the

test object. Reflected light is measured by the cell and indicated by a microammeter. Shades of colored specimens may be determined through the use of color filters. A built-in compensating circuit permits setting the instrument to zero when the reflection cell is placed on white or other light color standard. The instrument then reads 100 for black.

SMITH DEVICES, 2245 North 12th St., Philadelphia, Pa., has developed a variety of specialized materials-handling trucks. Among these are trucks for handling rolls of paper, drums, carboys, barrels, boxes, etc. Hand powered, they are designed to apply effective leverages for the conservation of manpower, and for safety in handling. Some types are equipped with brakes for handling on ramps and many with special loading devices.

THREE SIZES of Ammco tension indicating wrenches for use in the exact tightening of bolts on pressure equipment have been announced by the Automotive Maintenance Machinery Co., 2100 Commonwealth Ave., North Chicago, Ill. The three sizes have capacities up to 175, 420 and 1,000 ft.lb. respectively.

A NOVEL USE for Polaroid, the polarizing glass, has been developed by the American Optical Co., Southbridge, Mass., in a test for detecting fraudulent claims of industrial eye injuries. The test determines instantly whether or not an eye has actually suffered loss of sight. The equipment includes a projector and screen and a cross slide equipped with Polaroid lenses whereby test letters thrown on the screen can be polarized in either plane. The subject wears Polaroid spectacles and it is thus possible to cut off the line of sight between either eye and the test letters without the subject's suspecting it. This means that he cannot tell with which eye he is seeing, so that malingering is readily proved.

Chemical Porcelain

NOW AVAILABLE in a wide variety of shapes and sizes is a new line of chemical porcelain for industrial use which has recently been announced by the Lapp Insulator Co., LeRoy, N. Y. Among the designs offered are kettles, piping, filters, funnels, pitchers, jars, jar mills, evaporating dishes and tapered and cylindrical pots. The dense white body employed, similar to this company's electrical porcelain, is stated to be chemically stable and inert, and completely non-porous. The material is unaffected by acids except hydrofluoric, and is resistant to alkalis. A relatively low coefficient of thermal expansion makes the ware highly resistant to thermal shock, according to the manufacturer.

Most of the equipment is produced in a considerable range of size. Kettles for example, are made in sizes from 10 to 100 gal.; pots from 20 to 150 gal.; pipe from 1 to 8 in. i.d., and up to 60 in. in length; and evaporating dishes from 2 to 100 gal. Special shapes and sizes will be made if desired.

Electric Trucks

SEVERAL new electric trucks have recently been announced by the Elwell-Parker Electric Co., Cleveland, Ohio. The new Type ELN-10 tilting platform truck, illustrated herewith has a capacity of 10,000 lb. and is provided with an angle body locked on the platform, designed for steady rocking action under the control of the operator. Dumping can be accomplished at any height in the range of the platform. The truck is of the two-wheel drive and six-wheel steer type and is powered with a 500 per cent-overload, high-torque motor. Such materials as shredded pulp may be handled with this equipment.

Another new development is the Type F-11 handwheel-steered, tiering, tilting and telescoping fork truck for capacities to 5,000 lb. A dynamic brake supplements the travel brake and a solenoid brake on the hoist motor locks the load in position unless released by the application of power. Regenerative braking supplements the solenoid brake and returns current to the battery when the load is lowered. A third new development is the Type TQ heavy-duty tractor, which has an ultimate drawbar pull of 3,500 lb. and is equipped with four-wheel drive and four-wheel steer. A four-speed controller is used. Power is automatically shut off when the operator leaves his seat.

Explosion-Proof Motor

REDESIGN of its line of explosion-proof motors for improved appearance and mechanical and electrical characteristics, has been announced by the Louis Allis Co., Milwaukee, Wis. Both alternating- and direct-current motors are available, built to NEMA standards and suitable for Class 1 Group D explosive atmospheres. The motors are capable of operation in either horizontal or vertical position and have many design improvements such as extra heavy cast iron construction of the stator housing and end bells, ease of bearing inspection, use of cartridge type bearings, ease of maintenance, extra strength and complete waterproofness.

Variety of chemical porcelain shapes

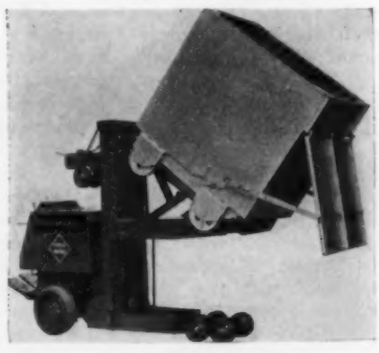
Hydraulic Action Controls

A NEW LINE of temperature controls employing a solid liquid-filled hydraulic-action thermal system has been announced by Julien P. Friez & Sons Division of Bendix Aviation Corp., Baltimore, Md. Owing to the large amount of switch-operating power available through expansion of the hydraulic-system liquid, these controls are capable of high load carrying capacity, for example, 15 amp. at 240 volts, a.c.

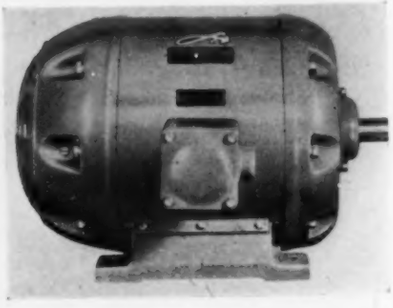
The high power available for switch operation is stated to be due to a newly perfected method of evacuating all traces of air or other gases from the liquid-charged element. The resulting expansion characteristics are said to compare with solid steel. The sensitive element is a metal bulb connected to a single diaphragm for direct transmission of movement to the switch. The latter employs positive snap action and positive contact and is claimed to be immune to any normal vibration. Silver double-break contacts are used.

The new type of control is available in a variety of instruments including boiler, furnace and fan controls, room thermostat, oven controls, space thermostats and refrigeration controls.

Tilting platform truck



Redesigned explosion-proof motor



MANUFACTURERS' LATEST PUBLICATIONS

Alloys. International Nickel Co., 67 Wall St., New York City—Bulletin C-7—12 pages on Monel and nickel kettles for paint, varnish and printing ink manufacture.

Alloys. The Riverside Metal Co., Riverside, N. J.—48-page book on phosphor bronze with information on properties, composition, applications and forms available. Includes history of company, types of service rendered and tables of useful information.

Alloy Tubes. Babcock & Wilcox Tube Co., Beaver Falls, Pa.—Technical Bulletin 12—Gives condensed technical data on high temperature steels with particular reference to seamless alloy tubes for high-pressure, high-temperature piping.

Alloy Tubes. Carpenter Steel Co., Welded Alloy Tube Div., Kenilworth, N. J.—Leaflet giving specifications, composition, available forms and available diameters and gages of this company's stainless steel tubing.

Boilers. Henry Vogt Machine Co., Louisville, Ky.—20-page bulletin on this company's Class ML-L low head boilers, giving detailed drawings of numerous installations.

Chemicals. R. & H. Chemicals Dept., E. I. duPont de Nemours & Co., Wilmington, Del.—Technical leaflet describing properties and uses of PVA polyvinyl alcohol.

Cleaning. Spencer Turbine Co., Hartford, Conn.—Bulletin 120—20 pages on industrial vacuum cleaning, showing examples in process industries and describing equipment.

Coatings. Amercoat Sales Agency, 5905 Pacific Blvd., Huntington Park, Calif.—12-page booklet describing uses and application procedure for various types of Amercoat cold-applied, corrosion-resisting, plastic coatings.

Coatings. American Pipe & Steel Corp., Alhambra, Calif.—8 pages describing this company's Armor-Clad method of coating for the protection of pipe lines.

Compressors. Ingersoll-Rand Co., 11 Broadway, New York City—Form 3426-1—12-page bulletin describing large "four-corner," direct-connected, synchronous-motor-driven compressors of this company's PRE line, built in sizes from 700 to 3,000 hp.

Control. Mason-Neilan Regulator Co., 1190 Adams St., Boston, Mass.—Bulletin 201-B—8 pages on steam-pump speed governors and the valves used in connection with them.

Conveyors. Mathews Conveyor Co., Ellwood City, Pa.—Catalog HB-39—384-page conveyor handbook, giving design, dimensions and engineering information on numerous types of conveyors made by this company including roller, belt, chain and elevating conveyors, each in various modifications.

Conveyors. Pioneer Rubber Mills, 353 Sacramento St., San Francisco, Calif.—Folder designed to assist conveyor and elevator belting users in choice of proper types.

Dryers. Koppers - Rheolaveur Co., Pittsburgh, Pa.—Folder describing the use of the Carpenter centrifugal dryer in all industries having granular materials to be dried. Also leaflet on wedge-wire screens for moisture removal.

Dust Collectors. American Foundry Equipment Co., 555 Byrkit St., Mishawaka, Ind.—New circular describing this company's assembled type Dustube dust collectors, with information on construction and mechanical features.

Electrical Equipment. Crocker-Wheeler Electric Mfg. Co., Ampere, N. J.—Bulletin 251-A—12 pages describing in detail principle and applications of this company's new alternating current Polyspeed motor, developed for adjustable speed service.

Electrical Equipment. The Okonite Co., Passaic, N. J.—Bulletin OK-2007A—8 pages describing this company's Okolite insulated cable for severe outdoor and indoor use, with data on efficiency, load carrying and moisture resistance.

Electrical Equipment. Roller Smith Co., Bethlehem, Pa.—Catalog 8-a—16 pages describing a variety of types of metal-clad switchgear for indoor service in industrial plants.

Electrical Equipment. Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.—Descriptive Data 31-132—12 pages describing industrial direct-current switchboard for smaller plants.

Equipment. Allis-Chalmers Mfg. Co., Milwaukee, Wis.—Publications as follows: Bulletin 1261-B, Vari-Pitch Texrope sheaves for power transmission; 1267, Interplane grinder for grinding, shredding and refining a large variety of materials; 1833-A, Utah electromagnetic feeders, conveyors and screens; 2354, heavy-duty gyratory sifters.

Equipment. Denver Equipment Co., 1400 Seventeenth St., Denver, Colo.—Bulletin SOB—Brief description of this company's equipment, listing numbers and sizes of various types available for immediate shipment, including such equipment as crushers, ball mills, classifiers, flotation machines, filters, pumps and thickeners.

Equipment. Worthington Pump & Machinery Corp., Harrison, N. J.—Publications as follows: W-321-B13, close-coupled turbine-driven pumps; W-341-B4, two-stage centrifugal pumps for refinery service; W-341-B5, single-stage centrifugal pumps for refinery service; S-500-B36, vertical, four-cycle, direct-injection diesel engines.

Instruments. The Foxboro Co., Foxboro, Mass.—Leaflet DMF748—2-page article reprint describing production improvements through the use of temperature controllers in a varnish plant.

Instruments. Julien P. Friez & Sons Div., Bendix Aviation Corp., Baltimore, Md.—Catalog K—24 pages describing and listing prices of this company's controlling, measuring and recording instruments, particularly for temperature, pressure and humidity.

Instruments. Leeds & Northrup Co., 4901 Stenton Ave., Philadelphia, Pa.—Catalog EN-95—40-page book completely describing this company's apparatus for electrolytic conductivity measurements in laboratories and plants.

Instruments. F. J. Stokes Machine Co., Olney P. O., Philadelphia, Pa.—Bulletin 902—Six page leaflet describing this company's new McLeod type portable vacuum gage.

Instruments. Taber Instrument Co., North Tonawanda, N. Y.—Bulletin 3802-Rev.1—6 pages describing this company's improved Type V-5 stiffness gage for paper and other thin materials.

Insulation. Quigley Co., Inc., 56 West 45th St., New York City—Bulletin 320-D—4-page leaflet describing this company's Insulcrete, a light-weight insulating refractory concrete for direct exposure to flames up to 2,500 deg. F.

Materials Handling. Smith Devices, 2245 North 12th St., Philadelphia, Pa.—6-page folder describing a wide variety of special trucks made by this company for the handling of drums, barrels, rolls of paper and other difficultly handled packages.

Mixers. Pneumix Division, Eclipse Air Brush Co., 390 Park Ave., Newark, N. J.—4-page folder describing this company's direct- and gear-driven air-motored agitators.

pH Instruments. National Technical Laboratories, 3330 East Colorado Street, Pasadena, Calif.—Bulletin 16—8 pages describing in considerable detail this company's model R pH meter and industrial type glass electrodes.

Power Transmission. Ideal Commutator Dresser Co., Sycamore, Ill.—4-page leaflet describing this company's Select-O-Speed variable speed transmissions, including a new type controlled by means of a hand wheel.

Pumps. Beach-Russ Co., 50 Church St., New York City—Bulletin 72—4-page folder describing a new line of Type RP high vacuum pumps for pressures within 10 microns Hg of absolute.

Refractories. McLeod & Henry Co., Troy, N. Y.—1939 catalog on furnace refractories, describing and illustrating this company's complete line of materials and designs, including fire-clay, silicon-carbide and alumina refractories and high temperature cements.

Safety. Chicago Eye Shield Co., 2300 Warren Blvd., Chicago, Ill.—24th Catalog Edition—48 pages on industrial head and eye protection, describing numerous types of goggles, masks, respirators and other safety equipment with table listing recommended respirator cartridges for protection against various gases, dusts and fumes.

Safety. Mine Safety Appliances Co., Braddock, Thomas & Meade Sts., Pittsburgh, Pa.—Bulletin CE-8—4 pages describing this company's various types of goggles for eye protection.

Screens. The J. H. Day Co., Cincinnati, Ohio—Bulletin 375—12 pages on this company's Ro-Ball gyrating screens with description of features and list of materials handled.

Scrubbers. Peabody Engineering Corp., 580 Fifth Ave., New York City—4-page leaflet describing this company's new triple-action scrubber for the cleaning of gas and air.

Separators. Stearns Magnetic Mfg. Co., Milwaukee, Wis.—Bulletin 97—describes this company's spout type magnetic separators, giving complete specifications.

Traps. W. H. Nicholson & Co., Wilkes-Barre, Pa.—Bulletin 439—8 pages on this company's thermostatic industrial steam traps; also bulletin 339 on welded stainless steel and chromium plated steel floats.

Valves. Crosby Steam Gage & Valve Co., 30 Church St., New York City—Leaflet F 1544—2 pages describing this company's style JJC nozzle relief valves for pressures to 1,800 lb. and temperatures to 900 deg. F.

Valve Disks. Goetze Gasket & Packing Co., New Brunswick, N. J.—Leaflet describing and listing prices of this company's recently improved disks for renewable-disk-type valves.

Water Treatment. Philadelphia Quartz Co., 121 South 3d St., Philadelphia, Pa.—Bulletin 373—6 pages on the control of water corrosion through the use of sodium silicates.

Welding. The Vulcan Boiler & General Insurance Co., Ltd., Manchester, England—40-page book of "Notes on Metallic-Arc Fusion Welding of Steam Pressure Vessels." Describes types of welds, quality required, metallurgical considerations and methods employed in testing. Considerable information is given on types of defects.

Wood Treatment. Allis-Chalmers Mfg. Co., Milwaukee, Wis.—Bulletin 1834—32 pages on machinery for wood preservation, describing effects of treatment, types of processes and machinery required.

Chemical Engineering NEWS

Nitrate Distributors Deny F.T.C. Complaint

The Chilean Nitrate Sales Corp. and The Barrett Co. have been charged with restraint of trade in violation of the Federal Trade Commission Act and with price discrimination in violation of the Robinson-Patman Act, in a complaint issued by the Commission. The complaint alleges that the companies monopolize the supply and distribution of raw nitrate of soda in the United States and charges them with entering into agreements to control the sale and distribution of their products by establishing, fixing, and maintaining the prices at which, and the conditions under which, both bagged and bulk nitrate of soda shall be sold to distributors and fertilizer manufacturers and resold to dealers and consumers.

The Chilean Nitrate Sales Corp. has denied the charges. It stated that it does not have any agreement whatsoever with The Barrett Co. and that the two companies do not cooperate in issuing bulletins, price lists, and other printed matter.

The Barrett Co. has denied the charges stating that prior to the war Chile was the sole source of nitrate of soda used throughout the world for explosives and for fertilizer. According to the Report of the War Industries Board, during the war the price of nitrate advanced to as high as $150 per ton. The average price paid by the United States Government during that period amounted to $82.50 per ton.

In the last ten years, competition in nitrates in this country, the largest market in the world and which is without tariff protection of any kind, has been intense. When the construction of the Hopewell plant commenced, the market price of nitrate of soda was $50 per ton in bulk at ports. The present price is $27 per ton.

Numerous Technical Sessions For A.S.T.M. Meeting

Upwards of twenty separate technical sessions will be necessary at the annual meeting of the American Society for Testing Materials to be held, June 26-30, at Chalfonte-Haddon Hall, Atlantic City, N. J., to provide for the presentation of the large number of technical papers and reports. Quite a number of the sessions will be in the nature of round-table discussions and others will feature symposiums comprising several papers on a particular subject. Throughout the week of the meeting, there will be in progress the Fifth Exhibit of Testing Apparatus and Related Equipment, and also the Society's Photographic Display, which this year will be devoted to the theme "Testing and Research in Engineering Materials."

Among the important technical features are Discussions on Paint Testing, Shear Testing of Soils, Quantitative Spectrochemical Analysis, Effect of Subatmospheric Temperatures on the Properties of Metals, and Freezing and Thawing. There will be groups of papers also covering water, fatigue of metals, asphalt, radiography, and concrete and concrete aggregates.

A.I.Ch.E. Announces Problem Contest Winners

John F. Pelton, a member of the University of Tennessee chapter, has been declared the winner of first prize in the American Institute of Chemical Engineer's 1938-39 problem contest. He thereby receives the A. McLaren White Award, a check for $100.

Mr. Pelton has taken the cooperative course in chemical engineering, having been employed by the Fulton-Sylphon Co., the Tennessee Eastman Corp., and the Chemical Engineering Research Division of the T.V.A.

Robert C. Holmes, of the University of Illinois chapter, has been awarded the second prize of $50. He has been a consistent leader in his class, and won the 1937 Chapter Award of the Institute, having the highest scholastic rating of any sophomore in chemical engineering in his chapter.

Third prize, a check for $25, was won by Robert Herzog of the Cooper Union chapter. He is a native of New York City, and has won scholarships during each of his four years at Cooper Union.

Carbon Dioxide Research Project Sponsored

To attain the objective of determining the basic principles of gas storage, and reducing these principles to practical economical applications in a minimum time, the American Institute of Refrigeration has sponsored a Carbon Dioxide Research Project and appointed the nucleus of a general committee, consisting of outstanding authorities in the various food fields: Dr. E. H. Harvey, of Wilson & Co., heads the committee, with Dr. M. E. Pennington, Dr. S. C. Prescott, Gardner Poole and G. A. Horne, as members. Every member of this group, representing the scientific laboratories and the refrigeration industry, is contributing his time and advice without remuneration, for the purpose of advancing this development as rapidly as possible.

The general committee will have complete charge of the Carbon Dioxide Research program and will assign research work and allot the money to be spent on each major food product. Advisory Committees, for each of the major food products, will meet regularly to make recommendations to the General Committee.

Manufacturing Chemists will Meet at Skytop

The sixty-seventh annual meeting of the Manufacturing Chemists' Association will be held at Skytop Lodge, Pa., June 1-2. The business session will open on the morning of June 1, with E. M. Allen presiding. Following committee reports and election of officers, W. B. Bell, Henry Clifton, Jr., and Charles F. Kettering will deliver addresses. The Synthetic Organic Manufacturers Association will meet at the same time and on the evening of June 1, will act as host to M.C.A. at a union dinner at which the speaker will be Dr. Robert C. Clothier, president of Rutgers University.

Barrett Co. Will Build New Phenol Plant

The Barrett Co., a subsidiary of Allied Chemical & Dye Corp., has announced that it will at once start on the construction of a new unit at its plant at Frankford, Pa. The new unit will be used for production of synthetic phenol which, it is explained, will be used to supply the rapidly expanding requirements of the domestic plastics industry.

Monsanto Acquires Business of Resinox Corp.

Acquisition of Resinox Corp., third largest manufacturer of phenolic plastics molding compounds, was announced on May 4 by Monsanto Chemical Co. Resinox, with offices in New York, and manufacturing plant and research laboratories at Edgewater, N. J., was owned jointly by Commercial Solvents Corp. and the Corn Products Refining Co.

Monsanto's acquisition of Resinox is its second major move in the plastics industry in thirteen months. On April 1, 1938, the Fiberloid Corp., Springfield, Mass., pioneer maker of plastics, became the Plastics Division of Monsanto.

NEWS FROM WASHINGTON

Washington News Bureau
McGraw-Hill Publishing Co.
Paul Wooton, Chief

CONGRESS will not go home soon. Early adjournment talk is misleading. Even a Washington Summer is less terrifying than the thought that the President would have complete control of the political situation, and could use the sounding board of his important office without any chance for reply through the megaphone of Congressional activity. Since control of the Democratic party in 1940 is still at stake, anti-New Dealers want to keep Congress in session—and will.

This means that there is some chance for passage of legislation wanted by business. Such measures as tax revision, limitation of N.L.R.B., and like business-relief enactments will have no chance of completion until late Summer. If Congress stays that long, as now expected, there is a slight margin in favor of the passage of a few such measures. Although these bills are opposed by the President, it is not at all sure that he dare veto them. To do so would give political encouragement to his reform voters, but would antagonize too many small business men.

With this situation in view, Washington representatives of organized business are quietly, almost stealthily, encouraging the conservative members of Congress to stay on as long as possible.

Military Problems

Washington is badly fatigued by recurring war crises. It is getting almost indifferent to them. Those who are anxious to have a return to serious consideration of domestic problems feel a bit encouraged, and expect to accomplish something real during May and June if Danzig and the Polish Corridor remain in status quo.

It now looks as though the Army and Navy Munitions Board will have $100,000,000 to spend on strategic materials. Initial emphasis will be on imported mineral commodities like manganese, chromium, antimony, tin and quicksilver. But the building of stock piles of rubber, quinine, cordage fibers, and other process industry raw materials will also be an important part of the program. Advisory committees on all important military commodities are working quietly behind the scenes, bringing up to date the information which the War and Navy Departments must use in programing their further purchases.

Barter of cotton and wheat for tin and rubber will be the limit of that sort of preparedness trading. If Ambassador Kennedy can negotiate such a deal, it will not interfere with stock pile buying, but simply permit somewhat different allocation of the money.

New Fish Oil Supply

The American salmon industry has a potential supply of 10,000,000 lb. a year of a marine oil, only 15 per cent of which is now being used. Interest in this national resource has been aroused by recent investigations of the Bureau of Fisheries, the technologists of which have reported the properties of the oil as follows:

The oil is unsaturated, ranging from an approximate iodine number of 100 for Chinook salmon to over 170 for pink salmon. Vitamin potency is high, both in A (100 to 1500 units per gram) and in D (90 to 125 units per gram). Broadly speaking, the oils in the waste from the average salmon cannery contain 2 per cent free fatty acid and a like percentage of unsaponifiable matter. The saponification number is about 185, the refractive index is 1.475, and the specific gravity 0.92. Although the oil is highly pigmented, the color is easily removed. As the properties of this oil are better known, uses may soon be found for these domestic cannery wastes in the Pacific Northwest.

News "Fines"

Standard Cans—Packers of fruits and vegetables have adopted 33 standard sizes of cans for the 53 products which they pack. Chemical folks using a similar type of can may find cost advantage in using one of these standard sizes in the future.

Nitrate Price Fixing—The Federal Trade Commission charges Chilian nitrate importers and the Barrett Company with conspiracy in the division of markets and price fixing, contrary to anti-trust laws, by a complaint which promises to air marketing practices in this industry.

Youthful Workers—The Childrens' Bureau has ruled that makers of explosives and of goods containing explosive compounds, such as fireworks, may not employ minors under 18 years of age. Like rulings are expected for other "hazardous" activities of chemical enterprise.

Truck Driver Rules—If the I.C.C. does not take over regulation of motor vehicle drivers, even those working for private owners of trucks, then the wage-hour law will apply. This means that drivers working locally but handling goods that subsequently get into interstate commerce are fully controlled by federal rulings.

New Ceramic Lab.—The Bureau of Mines will have $75,000 next year to operate the ceramic lab at Norris, Tennessee, which T.V.A. is surrendering to it. New studies will include particularly electro-technical methods for processing of non-metallics, and will not be limited to ceramic and glass methods and materials, as formerly. Substantial increase in non-metallic beneficiation studies at the Tuscaloosa lab. is also planned by the Bureau.

Wage-Hour Law—Amendments wanted by Administrator Andrews will be granted by Congress; but general amendment to the law is not expected. Critics cannot get what they want generally; friends dare not ask for strengthening lest the critics get their toe in the door.

"Intrastate" is No More—Two decisions of the Supreme Court on April 17 practically destroyed any remaining concept of intrastate business. A manufacturer who sells his goods within a state is still subject to federal regulation on his labor matters if the goods go out of the state after he sells them. And Uncle Sam can regulate the interstate movement of agricultural [or other] goods, even though he may not directly prohibit the quantity produced. One has grave difficulty in finding anything left which Uncle Sam may not effectively, though indirectly, control under these rulings.

Answer, or Else!—The Commerce Department, acting for T.N.E.C., tried to get cooperative reports from 2300 trade associations. About 250 did not reply, up to May 1. *They* were told "In the case of those associations which are unwilling to cooperate, we will subpoena the appropriate officials . . . ." This may not be regarded as either "cooperation" or "voluntary", which were the much emphasized words early in the game.

State Labor Laws—Washington reformers grieve that most of the state legislatures are adjourning without enactment of the state equivalent of NLRB. Critics of that body hope that Congressional delegations from these states will interpret this as meaning that the Wagner Act is not too popular back home, needs revision this year.

Interstate Barriers—Florida must not impose a tax equivalent to an import duty on cement made elsewhere. This, in effect is the Supreme Court ruling which forbids continuance of the 15 cents-per-hundredweight inspection levy made by Florida under the guise of protecting its citizens against inferior cement importation. Any division of process industry disturbed by such interstate tax barriers now has the Supreme Court's word for it that such things must not be.

Chemical ECONOMICS and MARKETS

CONSUMING INDUSTRIES REDUCED RAW MATERIAL REQUIREMENTS LAST MONTH

SLOWER rates of operation in the fertilizer, pulp and paper, steel, rayon, and textile industries brought a decline in the volume of chemical consumption for April. Based on preliminary data *Chem. & Met.'s* index for chemical consumption dropped back close to 114 in April from the relatively high level of 118.58 reached in March. Reports from the various industries agree that first quarter results were on an average considerably higher than for the corresponding period of last year.

Rayon figures were especially pleasing as the quarter registered new records both for production and consumption of yarn. In addition, earlier advices of increased outputs of staple fiber were borne out as staple production was given as 11,000,000 lb.

Some slowing up has been heard regarding activities in the pulp and paper industry in recent weeks but statistical reports have been incomplete and revisions for 1938 pulp statistics are said to be under way. Production of paperboard has been notably high with an output of 421,576 tons in March which was the largest monthly total since April, 1937.

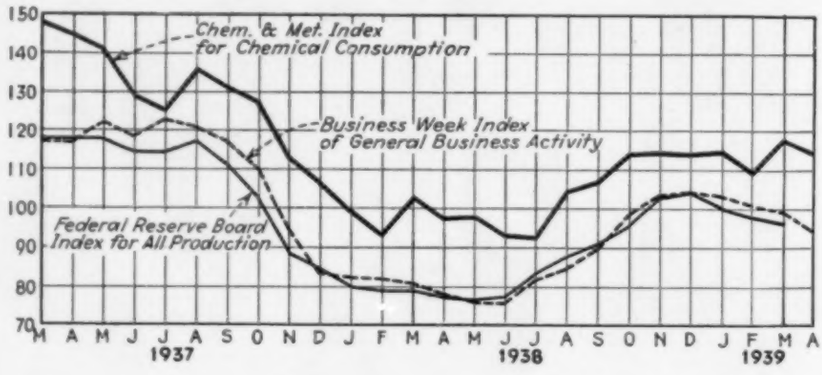
A report from the Department of Commerce states that manufacturers sales during March were 9.9 per cent above the level of March last year, this statement being based on reports from 1,715 manufacturers. Sales for these manufacturers were up 16.6 per cent from February. Gains in dollar sales over the March 1938 figures were general. Percentage gains for some of the groups were as follows: textiles and their products, 10; paper and allied products, 9.3; chemicals and allied products, 11.3; paints and varnishes, 8.2; pharmaceuticals and proprietary medicines, 16.9; other chemical products, 11.6; rubber products, 25.9; leather and products, 14.4; stone, clay, and glass products, 10.

Manufacturers' sales during the first three months of 1939 were up 10.3 per cent from the same period of 1938, according to reports of 1,616 manufacturers. Increases were well distributed throughout the major industry groups for which data are shown separately. Printing, publishing and allied products, and petroleum products were the only industry groups which did not attain the 1938 level.

The total dollar volume for the first three months of 1939 was 926 million dollars as compared with 839 million dollars for the corresponding period of last year. Exceptional gains were recorded for four of the major industry groups. Iron and steel and their products, motor vehicle parts, nonferrous metals and their products, and rubber products, registered increases of 43.4 per cent, 41.4 per cent, 36.3 per cent, and 31.9 per cent respectively.

Production of oils and fats for the first quarter of this year was approximately 70,604 thousand pounds less than in the corresponding quarter of 1938 but as production of crude cottonseed oil was almost 205,000 thousand pounds below the 1938 total, the loss was entirely in that direction and production of most other oils and fats was considerably higher in the 1939 quarter. For the first time the Bureau of the Census gives a production figure for tung oil with a first quarter output of 1,085,150 lb.

Domestic production of vegetable oils is still featured by the rising importance of soybean oil. In the first three months of this year production of crude soybean oil was 121,289,014 lb. and consumption was 102,697,936 lb. For the like 1938 period, production was 81,570,327 lb. and consumption was 59,905,734 lb. Figures for refined soybean oil are, 1939, production 91,919,309 lb. and consumption 75,111,213 lb. For 1938, 51,864,348 lb., and 49,635,343 lb.



***Chem & Met.* Index for Consumption of Chemicals**

	February (Revised)	March
Fertilizer	24.66	23.60
Pulp and paper	15.15	15.30
Glass	9.60	11.60
Petroleum refining	11.46	13.01
Paint and varnish	8.25	10.68
Iron and steel	6.54	7.05
Rayon	8.30	9.04
Textiles	7.13	7.99
Coal products	6.23	6.96
Leather, glue, and gelatine	4.48	4.63
Explosives	3.88	4.06
Rubber	2.38	2.76
Plastics	1.76	1.90
	109.82	118.58

Production and Consumption Data for Chemical-Consuming Industries

	March 1939	March 1938	January–March 1939	January–March 1938	Per cent of gain for 1939
Production					
Alcohol, ethyl, 1,000 pr. gal	17,423	18,329	49,161	50,701	3.0*
Alcohol, denatured, 1,000 wi. gal.	7,616	6,207	20,898	17,178	21.7
Ammonia liquor, 1,000 lb	4,434	3,804	12,671	10,830	17.0
Ammonium sulphate, 1,000 lb	93,339	73,167	268,412	215,599	24.5
Benzol, 1,000 gal	8,063	5,998	22,992	17,728	29.7
Byproduct coke, 1,000 tons	3,439	2,675	9,883	7,931	24.6
Glass containers, 1,000 gr	4,129	3,637	11,107	9,757	13.8
Plate glass, 1,000 sq. ft	11,867	3,802	34,241	11,585	195.6
Rubber reclaimed, tons	14,528	6,875	41,384	20,354	103.3
Consumption					
Cotton, bales	649,237	512,626	1,803,521	1,372,750	31.4
Silk, bales	37,863	34,884	111,898	95,859	16.7
Wool, 1,000 lb	30,966	14,740	97,916	47,193	107.5
Automobiles, factory sales	371,940	221,795	1,008,973	617,854	63.3
Rubber, crude, tons	50,165	30,487	138,764	83,784	65.6
Waste paper, tons	292,474	243,571	773,495	662,042	16.8
Explosives, 1,000 lb	27,801	23,425	83,650	75,786	10.4

* Per cent of decline.

Current PRICES

INDUSTRIAL CHEMICALS

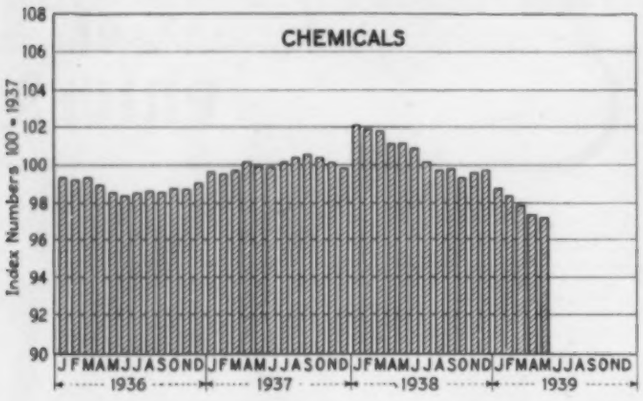
	Current Price	Last Month	Last Year
Acetone, drums, lb.	$0.05½–$0.06½	$0.05½–$0.06½	$0.05½–$0.06½
Acid, acetic, 28%, bbl., cwt.	2.23 – 2.48	2.23 – 2.48	2.23 – 2.48
Glacial 99%, drums	8.43 – 8.68	8.43 – 8.68	8.43 – 8.68
U. S. P. reagent	10.25 –10.50	10.25 –10.50	10.25 –10.50
Boric, bbl., ton	106.00–111.00	106.00–111.00	105.00–115.00
Citric, kegs, lb.	.20½– .23	.21½– .24	.24 – .27
Formic, bbl., ton	.10½– .11	.10½– .11	.10½– .11
Gallic, tech., bbl., lb.	.70 – .75	.70 – .75	.75 – .78
Hydrofluoric 30% carb., lb.	.07 – .07½	.07 – .07½	.07 – .07½
Lactic, 44%, tech., light, bbl., lb.	.06½– .06¾	.06½– .06¾	.06½– .06¾
Muriatic, 18°, tanks, cwt.	1.05 –.....	1.05 –.....	1.05 –.....
Nitric, 36°, carboys, lb.	.05 – .05½	.05 – .05½	.05 – .05½
Oleum, tanks, wks., ton	18.50 –20.00	18.50 –.....	18.50 –20.00
Oxalic, crystals, bbl., lb.	.10½– .12	.10½– .12	.10½– .12
Phosphoric, tech., c'bys., lb.	.07½– .08½	.07½– .08½	.09 – .10
Sulphuric, 60° tanks, ton	13.00 –.....	13.00 –.....	13.00 –.....
Sulphuric, 66°, tanks, ton	16.50 –.....	16.50 –.....	16.50 –.....
Tannic, tech., bbl., lb.	.40 – .45	.40 – .45	.40 – .45
Tartaric, powd., bbl., lb.	.27½–.....	.27½–.....	.25½–.....
Tungstic, bbl., lb.	2.35 –.....	2.35 –.....	2.75 –.....
Alcohol, Amyl	.....	.....	.....
From Pentane, tanks, lb.	.101–.....	.101–.....	.123–.....
Alcohol, Butyl, tanks, lb.	.07½–.....	.07½–.....	.08½–.....
Alcohol, Ethyl, 190 p'f., bbl., gal.	4.54 –.....	4.54 –.....	4.14 –.....
Denatured, 190 proof	.....	.....	.....
No. 1 special, bbl., gal. wks.	.26½–.....	.26½–.....	.31 –.....
Alum, ammonia, lump, bbl., lb.	.03½– .04	.03½– .04	.03 – .04
Potash, lump, bbl., lb.	.03½– .04	.03½– .04	.03½– .04
Aluminum sulphate, com. bags, cwt.	1.15 – 1.40	1.15 – 1.40	1.35 – 1.50
Iron free, bg., cwt.	1.30 – 1.55	1.30 – 1.55	2.00 – 2.25
Aqua ammonia, 26°, drums, lb.	.02 – .03	.02 – .03	.02½– .03
tanks, lb.	.02 – .02½	.02 – .02½	.02½– .02½
Ammonia, anhydrous, cyl., lb.	.15½–.....	.15½–.....	.15½–.16
tanks, lb.	.04½–.....	.04½–.....	.04½–.16
Ammonium carbonate, powd. tech., casks, lb.	.08 – .12	.08 – .12	.08 – .12
Sulphate, wks, cwt.	1.40 –.....	1.40 –.....	1.475–.....
Amylacetate tech., tanks, lb.	.10½–.....	.09½–.....	.11 –.....
Antimony Oxide, bbl., lb.	.11 – .12	.11 – .12	.12½– .13
Arsenic, white, powd., bbl., lb.	.03 – .03½	.03 – .03½	.03 – .03½
Red, powd., kegs, lb.	.15½– .16	.15½– .16	.15½– .16
Barium carbonate, bbl., ton.	52.50 –57.50	52.50 –57.50	52.50 –57.50
Chloride, bbl., ton	79.00 –81.00	79.00 –81.00	79.00 –81.00
Nitrate, casks, lb.	.07 – .08	.07 – .08	.07 – .08
Blanc fixe, dry, bbl., lb.	.03½– .04	.03½– .04	.03½– .04
Bleaching powder, f. o. b., wks., drums, cwt.	2.00 – 2.10	2.00 – 2.10	2.00 – 2.10
Borax, gran., bags, ton	48.00 –51.00	48.00 –51.00	46.00 –51.00
Bromine, cs., lb.	.30 – .32	.30 – .32	.30 – .32
Calcium acetate, bags	1.65 –.....	1.65 –.....	1.65 –.....
Arsenate, dr., lb.	.06½– .07	.06½– .07	.06½– .07
Carbide drums, lb.	.05 – .06	.05 – .06	.05 – .06
Chloride, fused, dr., del., ton	21.50 –24.50	21.50 –24.50	21.50 –24.50
flake, dr., del., ton	23.00 –25.00	23.00 –25.00	23.00 –25.00
Phosphate, bbl., lb.	.07½– .08	.07½– .08	.07½– .08
Carbon bisulphide, drums, lb.	.05 – .06	.05 – .06	.05 – .06
Tetrachloride drums, lb.	.04½– .05½	.04½– .05½	.05½– .06
Chlorine, liquid, tanks, wks., lb.	1.75 –.....	1.75 –.....	2.15 –.....
Cylinders	.05½– .06	.05½– .06	.05½– .06
Cobalt oxide, cans, lb.	1.67 – 1.70	1.67 – 1.70	1.67 – 1.70
Copperas, bgs., f. o. b., wks., ton.	15.00 –16.00	15.00 –16.00	15.00 –16.00
Copper carbonate, bbl., lb.	.10 – .16½	.10 – .16½	.09 – .16
Sulphate, bbl., cwt.	4.10 – 4.35	4.35 – 4.60	4.25 – 4.50
Cream of tartar, bbl., lb.	.22½– .23	.22½– .23	.20½– .21
Diethylene glycol, dr., lb.	.22 – .23	.22 – .23	.22 – .23
Epsom salt, dom., tech., bbl., cwt.	1.80 – 2.00	1.80 – 2.00	1.80 – 2.00
Ethyl acetate, drums, lb.	.061–.....	.061–.....	.06½–.....
Formaldehyde, 40%, bbl., lb.	.05½– .06½	.05½– .06½	.05½– .6½
Furfural, dr., lb.	.10 – .17½	.10 – .17½	.10 – .17½
Fusel oil, ref. drums, lb.	.12½– .14	.12½– .14	.12½– .14
Glaubers salt, bags, cwt.	.95 – 1.00	.95 – 1.00	.95 – 1.00
Glycerine, c.p., drums, extra, lb.	.12½–.....	.12½–.....	.15½–.....
Lead:			
White, basic carbonate, dry casks, lb.	.07 –.....	.07 –.....	.06½–.....
White, basic sulphate, sck., lb.	.06½–.....	.06½–.....	.05½–.....
Red, dry, sck., lb.	.07½–.....	.0735–.....	.07 –.....
Lead acetate, white crys., bbl., lb.	.10 – .11	.10 – .11	.11 – .12
Lead arsenate, powd., bbl., lb.	.10 – .10½	.11 – .11½	.13 – .13½
Lime, chem., bulk, ton	8.50 –.....	8.50 –.....	8.50 –.....
Litharge, pwd., csk., lb.	.06½–.....	.0635–.....	.06 –.....
Lithophone, bags, lb.	.04½– .04¾	.04½– .04¾	.04½– .05
Magnesium carb., tech., bags, lb.	.06 – .06½	.06 – .06½	.06 – .06½
Methanol, 95%, tanks, gal.	.31 –.....	.31 –.....	.31 –.....
97%, tanks, gal.	.32 –.....	.32 –.....	.32 –.....
Synthetic, tanks, gal.	.33 –.....	.33 –.....	.33 –.....
Nickel salt, double, bbl., lb.	.13 – .13½	.13 – .13½	.13 – .13½
Orange mineral, csk., lb.	.10½–.....	.10½–.....	.10 –.....
Phosphorus, red, cases, lb.	.40 – .42	.40 – .42	.40 – .42
Yellow, cases, lb.	.18 – .25	.18 – .25	.24 – .30
Potassium bichromate, casks, lb.	.08½– .09	.08½– .09	.08½– .09
Carbonate, 80–85%, calc. csk., lb.	.06½– .07	.06½– .07	.06½– .07
Chlorate, powd., lb.	.09½–.....	.09½–.....	.09½–.....
Hydroxide (c'stic potash) dr., lb.	.07 – .07½	.07 – .07½	.07 – .07½
Muriate, 80% bgn., unit.	.53½–.....	.53½–.....	.53½–.....
Nitrate, bbl., lb.	.05½– .06	.05½– .06	.05½– .06
Permanganate, drums, lb.	.18½– .19	.18½– .19	.18½– .19
Prussate, yellow, caks, lb.	.14 – .15	.14 – .15	.15 – .16
Sal ammoniac, white, casks, lb.	.05 – .05½	.05 – .05½	.05 – .05½
Salsoda, bbl., cwt.	1.00 – 1.05	1.00 – 1.05	1.00 – 1.05
Salt cake, bulk, ton	13.00 –15.00	13.00 –15.00	13.00 –15.00
Soda ash, light, 58%, bags, contract, cwt.	1.05 –.....	1.05 –.....	1.05 –.....
Dense, bags, cwt.	1.10 –.....	1.10 –.....	1.10 –.....
Soda, caustic, 76%, solid, drums, cwt.	2.30 – 3.00	2.30 – 3.00	2.30 – 3.00
Acetate, works, bbl., lb.	.04 – .05	.04 – .05	.04½– .05
Bicarbonate, bbl., cwt.	1.70 – 2.00	1.70 – 2.00	1.75 – 2.00
Bichromate, casks, lb.	.06½– .07	.06½– .07	.06½– .07
Bisulphate, bulk, ton	15.00 –16.00	15.00 –16.00	15.00 –16.00
Bisulphite, bbl., lb.	.03½– .04	.03½– .04	.03½– .04
Chlorate, kegs, lb.	.06½– .06¾	.06½– .06¾	.06½– .06¾
Cyanide, cases, dom., lb.	.14 – .15	.14 – .15	.16½– .17
Fluoride, bbl., lb.	.07½– .08	.07½– .08	.07½– .08
Hyposulphite, bbl., cwt.	2.40 – 2.50	2.40 – 2.50	2.40 – 2.50
Metasilicate, bbl., cwt.	2.20 – 3.20	2.20 – 3.20	2.15 – 3.15
Nitrate, bags, cwt.	1.45 –.....	1.45 –.....	1.45 –.....
Nitrite, casks, lb.	.06½– .07	.06½– .07	.07 – .08
Phosphate, dibasic, bags, lb.	1.85 –.....	1.85 –.....	1.85 – .024
Prussiate, yel. drums, lb.	.09½– .10	.09½– .10	.10 – .11
Silicate (40° dr.) wks., cwt.	.80 – .85	.80 – .85	.80 – .85
Sulphide, fused, 60–62%, dr., lb.	.02½– .03½	.02½– .03	.02½– .03
Sulphite, crys., bbl., lb.	.02½– .02½	.02½– .02½	.02½– .02½
Sulphur, crude at mine, bulk, ton.	16.00 –.....	16.00 –.....	18.00 –.....
Chloride, dr., lb.	.03 – .04	.03 – .04	.03 – .04
Dioxide, cyl., lb.	.07 – .08	.07 – .08	.07 – .07½
Flour, bag, cwt.	1.60 – 3.00	1.60 – 3.00	1.60 – 3.00
Tin Oxide, bbl., lb.	.50 –.....	.50 –.....	.46 –.....
Crystals, bbl., lb.	.38 –.....	.36 –.....	.32 –.....
Zinc, chloride, gran., bbl., lb.	.05 – .06	.05 – .06	.05 – .06
Carbonate, bbl., lb.	.14 – .15	.14 – .15	.14 – .15
Cyanide, dr., lb.	.33 – .35	.33 – .35	.36 – .38
Dust, bbl., lb.	.06½–.....	.06½–.....	.06½–.....
Zinc oxide, lead free, bag., lb.	.06½–.....	.06½–.....	.06½–.....
5% lead sulphate, bags, lb.	.06½–.....	.06½–.....	.06½–.....
Sulphate, bbl., cwt.	2.75 – 3.00	2.75 – 3.00	3.15 – 3.60

The accompanying prices refer to round lots in the New York market. Where it is the trade custom to sell f.o.b. works, quotations are given on that basis and are so designated. Prices are corrected to May 17

OILS AND FATS

	Current Price	Last Month	Last Year
Castor oil, 3 bbl., lb.	$0.08½–$0.10	$0.08½–$0.10	$0.09½–$0.10
Chinawood oil, bbl., lb.	.17½–.....	.15½–.....	.12 –.....
Coconut oil, Ceylon, tank, N. Y., lb.	.03¾–.....	.03¾–.....	.03⅝–.....
Corn oil crude, tanks (f. o. b. mill), lb.	.06 –.....	.05½–.....	.07½–.....
Cottonseed oil, crude (f. o. b. mill), tanks, lb.	.05¼–.....	.05¼–.....	.07 –.....
Linseed oil, raw car lots, bbl., lb.	.088–.....	.089–.....	.093–.....
Palm, casks, lb.	.03¼–.....	.03½–.....	.036–.....
Peanut oil, crude, tanks (mill), lb.	.05¼–.....	.05¼–.....	.07½–.....
Rapeseed oil, refined, bbl., gal.	.80 –.....	.80 –.....	.85 –.....
Soya bean, tank, lb.	.05 –.....	.04¼–.....	.05½–.....
Sulphur (olive foots), bbl., lb.	.06¼–.....	.06½–.....	.08½–.....
Cod, Newfoundland, bbl., gal.	.32 –.....	.32 –.....	.52 –.....
Menhaden, light pressed, bbl., lb.	.066–.....	.066–.....	.081–.....
Crude, tanks (f. o. b. factory), gal.	.30 –.....	.30 –.....	.35 –.....
Grease, yellow, loose, lb.	.05 –.....	.05 –.....	.04½–.....
Oleo stearine, lb.	.06½–.....	.06½–.....	.07½–.....
Oleo oil, No. 1	.07¼–.....	.07¼–.....	.08½–.....
Red oil, distilled, d.p. bbl., lb.	.07¼–.....	.07¼–.....	.09½–.....
Tallow extra, loose, lb.	.05¼–.....	.05¼–.....	.05½–.....

Chem. & Met.'s Weighted Price Indexes


CHEMICALS
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108
106
104
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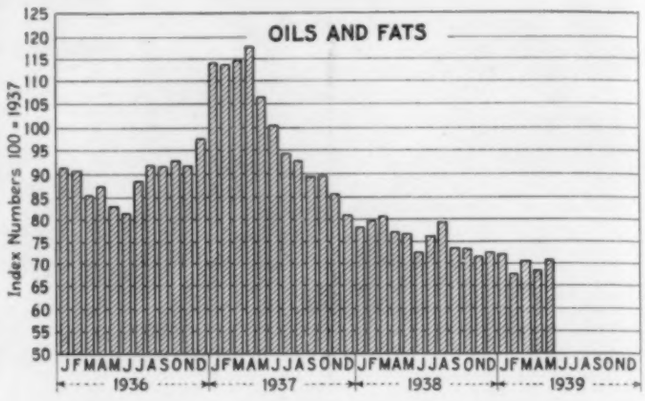
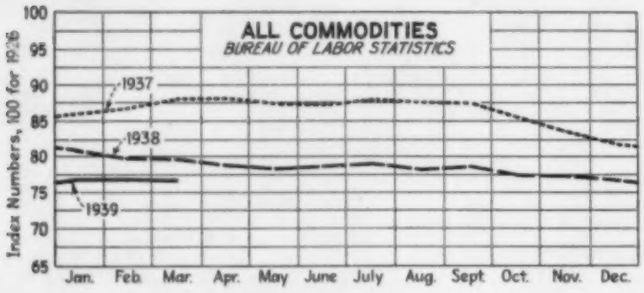
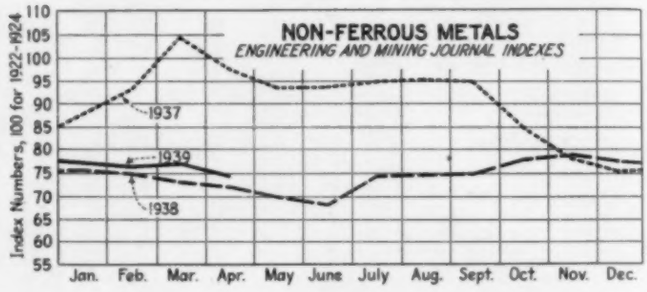






COAL-TAR PRODUCTS

	Current Price	Last Month	Last Year
Alpha-napthol, crude bbl., lb.	$0.52 –$0.55	$0.52 –$0.55	$0.52 –$0.55
Alpha-naphthylamine, bbl., lb.	.32 – .34	.32 – .34	.32 – .34
Aniline oil, drums, extra, lb.	.15 – .16	.15 – .16	.15 – .16
Aniline, salts, bbl., lb.	.22 – .24	.22 – .24	.22 – .24
Benzaldehyde, U.S.P., dr., lb.	.85 – .95	.85 – .95	.85 – .95
Benzidine base, bbl., lb.	.70 – .75	.70 – .75	.70 – .75
Benzoic acid, U.S.P., kgs., lb.	.54 – .56	.54 – .56	.54 – .56
Benzyl chloride, tech., dr., lb.	.23 – .25	.23 – .25	.25 – .27
Benzol, 90%, tanks, works, gal.	.16 – .18	.16 – .18	.16 – .18
Beta-napthol, tech., drums, lb.	.23 – .24	.23 – .24	.23 – .24
Cresol, U.S.P., dr., lb.	.10 – .11	.10 – .11	.12 – .13
Cresylic acid, dr., wks., gal.	.69 – .71	.69 – .71	.87 – .89
Diethylaniline, dr., lb.	.40 – .45	.40 – .45	.40 – .45
Dinitrophenol, bbl., lb.	.23 – .25	.23 – .25	.23 – .25
Dinitrotoluen, bbl., lb.	.15 – .16	.15 – .16	.15 – .16
Dip oil, 15%, dr., gal.	.23 – .25	.23 – .25	.23 – .25
Diphenylamine, bbl., lb.	.32 – .36	.32 – .36	.32 – .36
H-acid, bbl., lb.	.50 – .55	.50 – .55	.50 – .55
Naphthalene, flake, bbl., lb.	.05½– .06	.05½– .06	.06½– .07
Nitrobenzene, dr., lb.	.08 – .09	.08 – .09	.08 – .09
Para-nitraniline, bbl., lb.	.47 – .49	.47 – .49	.50 – .52
Phenol, U.S.P., drums, lb.	.14½–.....	.14½–.....	.14½–.....
Picric acid, bbl., lb.	.35 – .40	.35 – .40	.35 – .40
Pyridine, dr., gal.	1.55 – 1.60	1.55 – 1.60	1.55 – 1.60
Resorcinal, tech., kegs, lb.	.75 – .80	.75 – .80	.75 – .80
Salicylic acid, tech., bbl., lb.	.33 – .40	.33 – .40	.33 – .40
Solvent naptha, w.w., tanks, gal.	.26 –.....	.26 –.....	.30 –.....
Tolidine, bbl., lb.	.86 – .88	.86 – .88	.88 – .90
Toluene, tanks, works, gal.	.27 –.....	.27 –.....	.35 –.....
Xylene, com, tanks, gal.	.26 –.....	.26 –.....	.35 –.....

MISCELLANEOUS

	Current Price	Last Month	Last Year
Barytes, grd., white, bbl., ton.	$22.00–$25.00	$22.00–$25.00	$22.00–$25.00
Casein, tech., bbl., lb.	.07 – .11	.07½– .11	.06½– .12
China clay, dom., f.o.b. mine, ton.	8.00 –20.00	8.00 –20.00	8.00 –20.00
Dry colors			
Carbon gas, black (wks.), lb.	.02½– .30	.02½– .30	.02½– .30
Prussian blue, bbl., lb.	.36 – .37	.36 – .37	.36 – .37
Ultramarine blue, bbl., lb.	.10 – .26	.10 – .26	.10 – .26
Chrome green, bbl., lb.	.21 – .30	.21 – .30	.21 – .27
Carmine red, tins, lb.	4.00 – 4.40	4.00 – 4.40	4.00 – 4.40
Para toner, lb.	.75 – .80	.75 – .80	.75 – .80
Vermilion, English, bbl., lb.	1.57 – 1.58	1.57 – 1.58	1.45 – 1.50
Chrome yellow, C.P., bbl., lb.	.14½– .15½	.14½– .15½	.14½– .15½
Feldspar, No. 1 (f.o.b. N.C.), ton.	6.50 – 7.50	6.50 – 7.50	6.50 – 7.50
Graphite, Ceylon, lump, bbl., lb.	.06 – .06½	.06 – .06½	.06 – .06½
Gum copal Congo, bags, lb.	.06 – .30	.06 – .30	.08 – .30
Manila, bags, lb.	.07 – .14	.07 – .14	.09 – .14
Damar, Batavia, cases, lb.	.16 – .24	.16 – .24	.16 – .24
Kauri cases, lb.	.17½– .60	.17½– .60	.18½– .60
Kieselguhr (f.o.b. N. Y.), ton.	50.00 –55.00	50.00 –55.00	50.00 –55.00
Magnesite, calc, ton	50.00 –.....	50.00 –.....	50.00 –.....
Pumice stone, lump, bbl., lb.	.05 – .07	.05 – .08	.05 – .07
Imported, casks, lb.	.03 – .04	.03 – .04	.03 – .04
Rosin, H., bbl.	6.35 –.....	6.20 –.....	5.85 –.....
Turpentine, gal.	.30½–.....	.30½–.....	.29 –.....
Shellac, orange, fine, bags, lb.	.19 –.....	.19 –.....	.20 –.....
Bleached, bonedry, bags, lb.	.18 –.....	.18 –.....	.16½–.....
T. N. Bags, lb.	.10 –.....	.10 –.....	.11 –.....
Soapstone (f.o.b. Vt.), bags, ton.	10.00 –12.00	10.00 –12.00	10.00 –12.00
Talc, 200 mesh (f.o.b. Vt.), ton.	8.00 – 8.50	8.00 – 8.50	8.00 – 8.50
300 mesh (f.o.b. Ga.), ton.	7.50 –10.00	7.50 –10.00	7.50 –11.00
225 mesh (f.o.b. N. Y.), ton.	13.75 –.....	13.75 –.....	13.75 –.....

INDUSTRIAL NOTES

HERCULES POWDER CO., Wilmington, Del., has moved its New York office to 500 Fifth Ave. W. M. Annette is in charge with Rex St. Clair manager of explosives sales and C. C. O'Brien manager of naval stores sales.

VASCOLOY-RAMET CORP., North Chicago, Ill., is now operating its new plant at 415 Tonnelle Ave., Jersey City, N. J.

GLOBE STEEL TUBES CO., Milwaukee, is now represented in the Cincinnati territory by the Mutual Mfg. & Supply Co.

LINK-BELT CO., Chicago, has appointed Kenneth C. Ellsworth as manager of the stoker eastern division with headquarters at Philadelphia.

THOMAS TRUCK & CASTER CO., Keokuk, Iowa, has purchased the business of the Wm. H. Sippel Corp., South Bend, and has moved the machinery and equipment from the latter place to Keokuk.

THE C. M. KEMP MFG. CO., Baltimore, has appointed Byron L. Ashdown, Syndicate Trust Bldg., St. Louis, as representative in Missouri, Kansas, and part of Illinois and the Bridges-Wilson Corp., Boston as representative in eastern Massachusetts, Rhode Island, Maine and New Hampshire.

THE ESTERLINE-ANGUS CO., Indianapolis, has transferred H. L. Hildenbrand from Pittsburgh to act as sales representative in the New York area. Mr. Hildenbrand is located at 36-43 212th St., Bayside, L. I.

THE CORBORUNDUM CO., Niagara Falls, N. Y., has sent John Storm to New York as district sales manager to succeed Frank J. Harrington who has gone to the main office.

New CONSTRUCTION

PROPOSED WORK

Asbestos Pipe Factory—Asbestos Cement Pipes, Inc., 225 Bway., New York, N. Y., plans to construct a factory along the Erie R. R. near Saddle River Rd., Wood Ridge, N. J., for the manufacture of asbestos pipes. F. L. Smith & Co., 225 Bway., New York, N. Y., Archt. Estimated cost $300,000.

Cement Plant—H. J. Kaiser Co., Latham Sq. Bldg., Oakland, Calif., plans to construct a plant at Permanente Canyon (3 mi. northwest of Cupertino), Calif. Estimated cost $4,000,000.

Chemical Plant—Wm. F. Jobbins, Inc., North Lake St. Rd., Aurora, Ill., plans to rebuild its plant recently destroyed by fire. Estimated cost $50,000.

Chemical Plant—Smith Chemical Co., c/o F. E. Smith, Harlingen, Tex., plans to rebuild its plant and warehouse which was recently destroyed by fire. Estimated cost will exceed $40,000.

Chemical Plant—Unversal Chemical Co., Ltd., 2226 Oxford St., Vancouver, B. C., Can., contemplates the construction of a chemical plant. B. Russell, Mgr.

Distillery—Georgia Growers Distilling Co., c/o J. F. Moessmer, 17500 Riverside Dr., Cleveland, O., and J. C. McAuliffe, 796 Wilson Rd., Atlanta, Ga., plans to construct a 3 story distillery at Atlanta, Ga. A. Thomas Bradbury, William Oliver Bldg., Atlanta, Archt.

Distillery—Winnebago Distillery Co., c/o Paul Gerhardt, Archt., 447 Fullerton Pkway., Chicago, Ill., contemplates the construction of a distillery on a 30 acre tract on State Hy. No. 25, Kane Co., South Elgin, Ill. Estimated cost $750,000.

Factory—Cleveland Graphite Bronze Co., J. J. McIntype, Gen. Mgr., 880 East 72nd St., Cleveland, O., plans to construct a factory. Estimated cost $500,000.

Gas Recycling Plant—Atlantic Refining Co., Weslaco and Corpus Christi, Tex., plans to construct a natural gas recycling plant in the new gas distillate fields south of Weslaco, Tex. Estimated cost $450,000.

Gasoline Refinery—Continental Oil Co., Ponca City, Okla., plans to construct a crude oil distilling plant and 25,000,000 cu. ft. per day natural gasoline plant near Ville Platte, La. Estimated cost $500,000.

Oil Refinery—Utah Oil Refining Co., Utah Oil Bldg., Salt Lake City, Utah, has purchased a site at Pocatello, Idaho, and plans to construct a 3,000 bbl. combination topping and cracking refinery.

Rubber Factory—B. F. Goodrich Co., 500 South Main St., Akron, O., will soon award the contract for the construction of a factory for the manufacture of mechanical rubber goods, at Clarksville, Tenn. Estimated cost $1,500,000.

Soy Bean Processing Plant—McKee Feed & Grain Co., 500 East Second St., Muscatine, Ia., plans to construct a plant. Estimated cost $60,000.

Tile Factory—Pence Tile Works, Inc., c/o F. K. Pence, Pres., San Antonio, Tex., has purchased a site at Devine, Tex., and plans to construct a factory. T. N. Picnot, Consult. Engr. Estimated cost $100,000.

Where Plants Are Being Built in Process Industries

	Current Projects		Cummulative 1939	
	Proposed Work	Contracts	Proposed Work	Contracts
New England	.....	$875,000	$1,035,000	$275,000
Middle Atlantic	$300,000	1,165,000	2,890,000	9,408,000
South	2,040,000	5,000,000	7,733,000	3,625,000
Middle West	1,300,000	330,000	2,650,000	675,000
West of Mississippi	650,000	330,000	1,835,000	1,040,000
Far West	4,040,000	339,000	4,120,000	1,400,000
Canada	40,000	.....	4,950,000	2,115,000
Total	$8,370,000	$8,039,000	$25,213,000	$18,538,000

CONTRACTS AWARDED

Asphalt Plant—Standard Oil Co., Midland Bldg., Cleveland, O., has awarded the contract for an 80x300 ft. plant to Paugh & Brown, Inc., 6007 Euclid Ave., Cleveland. Estimated cost $50,000.

Distillery—Jos. Seagram & Sons Co., 7th St. Rd., Louisville, Ky., has awarded the contract for alterations and additions to its distillery at Lawrenceburg, Ind., to Ferro Concrete Construction Co., 203 West Third St., Cincinnati, O. Estimated cost $90,000.

Gas Extraction Plant—J. S. Abercrombe Co., Gulf Bldg., Houston, Tex., has awarded the contract for a gas extraction plant at Old Ocean, Tex., to Stearns-Rogers Co., 1720 California St., Denver, Colo. Estimated cost $90,000.

Laboratory—Baxter Laboratories, Inc., 923 Waukegan Rd., Glen View, Ill., has awarded the contract for a 1 story addition to its laboratory to Zanders Construction Co., 929 Waukegan Rd., Glen View. Estimated cost $50,000.

Laboratory—National Carbon Co., West 117th St. and Madison Ave., Lakewood, O., has awarded the contract for the construction of a 2 story, 60x120 ft. laboratory and office building at Fostoria, O., to Gillmore-Carmichael-Olson Co., 1873 East 55th St., Cleveland. Estimated cost $40,000.

Oil Refinery—Erickson Bros. Oil Co., 214 South Wabash St., St. Paul, Minn., plans to construct a refinery at Inger Grove bounded by Mississippi River, railway tracks and highway near St. Paul, Minn. Work will be started at once. Estimated cost $200,000.

Paper Mill—Hollingsworth & Whitney Co., 140 Federal St., Boston, Mass., has awarded the contract for a paper mill at Mobile, Ala., to Rust Engineering Co., Martin Bldg., Birmingham, Ala. Estimated cost including equipment $5,000,000.

Plywood Factory — Pacific Plywood Corp., subsidiary of Olympia Veneer Co., Jefferson and State Sts., Olympia, Wash., has awarded the contract for the construction of a plywood factory at Willamina, Ore., to Industrial Engineers & Contractors, Inc., 711 Middle Waterway, Tacoma, Wash. Estimated cost $94,000.

Porcelain Factory—McDanel Refractory Porcelain Co., 510 Ninth Ave., Beaver Falls, Pa., has awarded the contract for a factory building to O. R. McNutt, 11th and 5th Aves., New Brighton, Pa.

Roofing Factory—Lloyd A. Fry Roofing Co., 5302 West 66th St., Chicago, Ill., has awarded the contract for a group factory buildings at Northwest Yeon Ave. and 35th Ave., Portland, Ore., to Dougan-Hammond Construction Co., Rothschild Bldg., Portland. Estimated cost including equipment $200,000.

Soap Factory—Lever Bros., 164 Bway., Cambridge, Mass., has awarded the contract for a soap factory at Edgewater, N. J., to Stone & Webster, Inc., 49 Federal St., Boston, Mass., and 90 Broad St., New York, N. Y. Estimated cost $1,000,000.

Soap Factory—Procter & Gamble Co., Main and 6th Sts., Cincinnati, O., has awarded the contract for a soap factory at Quincy, Mass., to James Stewart & Co., 514 Statler Bldg., Boston, Mass. Estimated cost between $750,000 and $1,000,000.

Soy Bean Plant—Spencer-Kellogg & Sons, Inc., Niagara Sq., Buffalo, N. Y., has awarded the contract for an addition to its soy bean plant at Decatur, Ill., to James Stewart Corp., 343 South Dearborn St., Chicago, Ill. Estimated cost $125,000.

Tannery—Texas Tanning & Manufacturing Co., c/o C. C. Welhausen, Pres., Yoakum, Tex., plans to install a new unit at its plant here to specialize in the manufacture of products used in agricultural districts. Work will be done by owner.

Storage Plant—Universal Atlas Cement Co., 208 South LaSalle St., Chicago, Ill., has awarded the contract for the construction of a storage and distribution plant at Muskegon, Mich., to the Muskegon Construction Co., Muskegon, and the Lake States Engineering Co., 111 West Jackson St., Chicago. Estimated cost $100,000.

Benzol Refining Apparatus—Wheeling Steel Corp., Wheeling Steel Corp. Bldg., Wheeling, W. Va., has awarded the contract for the design and construction of Benzol refining apparatus and equipment at its Koppers by-product coke plant at Follansbee, W. Va., to include modernizing of the companies ammonium sulphate drying and tar removal equipment, to Koppers Co., Koppers Bldg., Pittsburgh, Pa.

Warehouse—Eastman Kodak Co., 241 Battery St., San Francisco, Calif., has awarded the contract for an addition to its plant to be used as a warehouse to Cahill Bros., 206 Sansome St., San Francisco. Estimated cost $45,000.

DELIVERIES OF HEAVY CHEMICALS CONTINUE TO EXCEED LAST YEAR'S QUOTAS

UNSEASONABLE weather conditions have had some effect in the way of delaying the movement of certain chemicals. In the case of fertilizer chemicals, encouragement is found in the report that sales of fertilizers in April, in 17 principal consuming states, amounted to 1,315,134 tons which represents an increase of 19 per cent over the sales of April, 1938. This condition is likewise found in the cases of other agricultural chemicals which have sold more freely in recent weeks, and the less than seasonal trade in the earlier part of the year apparently has been partially made up by later activities. While there has been a decline in total call for chemicals in the last month, demand has continued to stay ahead of the standards maintained a year ago. The coal strike has had some influence in retarding consumption of raw materials but this influence has not been large.

Reports on building permits and projected construction work continue to represent a large gain for the current year. Sales of paint and varnish are higher than last year but they do not yet reflect the percentage increase reported for building and for automotive output.

Prices for chemicals held a steadier course last month, that is there were fewer changes in the quoted lists. Large tonnage chemicals have shown no fluctuations in recent weeks but of the less important selections, changes, where made, generally were on the down side of the market and the weighted index number for the month was lowered slightly. Prices for oils and fats on the other hand were generally firmer. In the first place crude cottonseed oil was more firmly held and this usually has a corresponding effect on the status of the other oils. China wood oil has not been offered freely for shipment and uncertainty regarding shipments from primary markets has stiffened the market both here and abroad.

Consumption of drying oils during the quarter showed an appreciable gain over the first three months of last year with tung oil being consumed to the extent of 25,717,024 lb. as against 20,790,600 lb. for the 1938 quarter. Incidentally stocks of tung oil on March 31 this year were 53,712,099 lb. or 2,271,778 lb. more than on March 31, 1938. Production of linseed oil was 139,209,234 lb., factory consumption, 76,673,550 lb. with the corresponding figures for 1938 being, 125,587,390 lb. and 63,874,555 lb. respectively.

Deliveries of agricultural potash as reported by the American Potash Institute amounted to 12,028 tons of potash salts equivalent to 5,582 tons of K_2O. This refers to deliveries within continental United States, Canada, Cuba, Puerto Rico, and Hawaii and covers the first quarter of this year. In addition there were deliveries for chemical use of 7,986 tons of salts equivalent to 4,882 tons of K_2O.

The increased call for chemicals in plastics manufacture this year may be inferred from the fact that production of cellulose acetate plastics for the first three months amounted to 5,522,065 lb., divided 2,962,401 lb. sheets, rods, and tubes and 2,559,664 lb. molding composition. For the like period last year production was 2,220,864 lb., divided 850,550 lb. sheets, rods, and tubes and 1,370,314 lb. molding composition. For the same period production of nitrocellulose plastics in the form of sheets, rods, and tubes was 3,287,692 lb. in 1939 and 2,075,136 lb. in 1938.

Production and shipments of aluminum salts were substantially lower in 1938 than in 1937, according to the Bureau of Mines. Domestic production declined 11 per cent in quantity and shipments declined 12 per cent in quantity and 16 per cent in value. Total shipments of aluminum sulphate, the principal product of the aluminum salts industry, decreased from 424,568 short tons in 1937 to 374,248 tons in 1938, a drop of 12 per cent.

Aluminum salts imported during 1938 totaled 1,871 short tons valued at $40,189 compared with 2,864 tons valued at $61,665 in 1937. Exports of aluminum sulphate in 1938 totaled 27,715 short tons valued at $578,330 compared with 31,807 tons valued at $679,214 in 1937. Other aluminum compounds exported in 1938 amounted to 1,770 short tons valued at $257,545 compared with 2,609 tons valued at $426,363 in 1937. Alumina imports totaled 72 short tons valued at $5,464 in 1938 compared with 204 tons valued at $16,461 in 1937. Bauxite concentrates alumina exports in 1938 amounted to 15,643 short tons valued at $929,904 compared with 44,180 tons valued at $2,438,879 in 1937. Aluminum-salts manufacturers reported the consumption of 172,669 long tons of bauxite, 4,068 short tons of alumina, 610 tons of aluminum metal, and a small quantity of clay and alunite.

Exports of chemical and related products from the United States have advanced steadily and rapidly since the beginning of the current year, with most items entering into the trade sharing in the gains, according to the Department of Commerce.

Aggregating $10,815,000 in January, the value of such exports increased to $11,835,000 in February and to $15,054,000 in March, which compared with $14,000,000 in March of last year. An outstanding gain was recorded in exports of medicinals and pharmaceuticals, shipments of which were valued at $1,908,000 during March of this year against $1,497,500 during March, 1938. Exports of paints, pigments and varnishes also advanced substantially to a value of $2,069,000 compared with $1,673,500 in March, 1938. In this classification, shipments of ready-mixed paints, varnishes and lacquers increased from 406,000 gal. to 489,000 gal.

Following several months of declining trade exports of naval stores advanced sharply to a value of $1,185,000 in March compared with $707,000 in February, $742,000 in January, and $1,122,000 in March of last year.

Other items and classifications on the chemical and related product list recording export gains in March compared with March of last year included vegetable tanning extracts, shipments of which increased in value from $99,000 to $103,000; sulphur, both crude and refined, from $752,000 to $795,000; chemical specialties, from $2,307,000 to $2,487,000; industrial chemicals, from $2,136,000 to $2,261,000; industrial explosives, from $446,000 to $463,000; and toilet preparations from $526,000 to $608,000.

CHEM. & MET.

Weighted Index of

CHEMICAL PRICES

Base=100 for 1937

This month	**97.27**
Last month	97.48
May, 1938	100.24
May, 1937	99.97

The majority of chemicals were on an unchanged price basis but a few of the solvents were easier and copper sulphate was reduced in price. Some of the coal-tar chemicals are firmly held under light offerings.

CHEM. & MET.

Weighted Index of Prices for

OILS AND FATS

Base=100 for 1937

This month	**70.85**
Last month	68.25
May, 1938	76.79
May, 1937	106.48

Prices for animal fats were practically unchanged but cottonseed, China wood, soybean, peanut, and coconut oils were firmer and the index number advanced appreciably. Crude glycerine added to the strength of prices.

PROCESS EQUIPMENT DESIGN

DESIGN of process equipment may well be considered the keystone of the application of chemical engineering to that group of industries which we call the process field, and yet from the standpoint of a planned and coordinated literature, it has received scanty attention in comparison with the fundamentals of unit operations and unit processes. Why? No unit operation can be adapted to the carrying out of a unit process without design of equipment. No process can yield a useful product without the intervention of equipment at every step, all of which has been subjected to more or less careful design.

One clue to the dearth of a thorough-going literature of design doubtless lies in the fact that so much of design depends on experience, hard won and, therefore, often guarded for the competitive advantage that it gives. Another lies in the conception of the term "design" itself. Ask a dozen engineers, or a great many more as we did, what they understand by design, and you will get as many answers as there are answerers. Z. G. Deutsch, author of the article herein on packed and spray tower design, was so much interested in the question that he set himself to the task of defining his idea of design, and an excellent definition it is. "Design," says Author Deutsch, "is that thorough exercise of ingenious knowledge and painstaking skill in creating the specification for a work which, together with comparably good execution, results in the adequacy, beauty and economy of that work." A definition which makes any result less than practical perfection something less than design!

"Ingenious knowledge and painstaking skill—" truly the hallmark of a successful designer! But of what must that ingenious knowledge consist? The chemical engineer, when he is turned loose in industry, is a specialist in the *fundamentals* of the unit operations. Mechanical engineers on the other hand tend to a specialty of *mechanical* fundamentals—those things which go to make a machine successful as a *machine*. Both lack the third ingredient of ingenious knowledge, which is *experience*. Time may correct this last deficiency but still, without shaking the two engineers together in a bag, it generally takes both of them to do the job, and neither fully conversant with the other's language.

This is why chemical engineers need to know more about design; why a fuller literature is needed; why *Chem. & Met.* is here attempting to plot out a part of the territory for such a literature, with strong emphasis on the experience phase. Within the limits of 48 pages hardly more than the outlines of a series of chapters in some future book can be given, but it is a start. Intentionally, stress is laid upon design fundamentals, common to all design problems. Classes of equipment already well standardized are completely omitted and it is only with those types which generally must be tailor-made for the job that we have permitted our authors to become specific. Within the limits noted, 14 authors have contributed what is hoped will prove the embryo of a chemical engineering design literature, or at least the stimulus for its development.

Not every chemical engineer by any means aspires to be a designer. Some few may never have to specify a piece of equipment. For the rest, however, at least a long step toward the achievement that ingenious knowledge is needed if, as Author Manning demands on the next page, equipment is to have the benefit of "Design for Operation."

Design for Operation

BY PAUL D. V. MANNING, editorial representative of Chem. & Met. *and consulting chemical engineer of San Francisco, Calif. His 20 years of engineering experience in almost every branch of chemical industry have given him a broad perspective for dealing with this problem of process equipment design.*

DESIGN FOR OPERATION

WHEN A PROCESS has issued from the research laboratory in the form of a report and flow sheets, has passed the market research study, survived a siege in the pilot plant and has finally been approved by the "brass hats" in the front office, designing engineers take over. Fortunate is the operating department if the designer has had operating experience.

Because of their control on subsequent operation, the design of equipment and the plant itself are of first importance. Fabrication, erection and operation follow design. Cost of fabrication, erection and operation all depend on design to an extent greater than is usually realized. Since the ultimate proof of any process lies in cost and quality of product and these are contingent upon operation, we propose to consider here, those design factors which influence operation.

After all, the one first essential to keep in mind is that operation and not design is the primary purpose of all equipment. Design should therefore be subservient at every point to operation. It is a good idea for at least one of the designing engineers to participate as an operator in several shifts during the pilot plant operation.

General factors of design which directly affect costs of operation are the following:

Simplicity of Equipment—This needs no amplification. The simplest design is always best and can be operated and maintained at lowest cost.

Composition of Design—This can be determined by answering the question, "How good a composition does the job require?" For most economical and satisfactory operation, good enough is best. Excepting in the food industry where plants are often "dressed up" for advertising purposes, neatness and simplicity may be obtained without "gold plate." A study of the requirements of the process from both its technical and product standpoints will decide how far the design should go. Savings in first cost here will be reflected in lower depreciation and obsolescence charges plus a higher production per dollar invested. Where sale of equipment is concerned it may be the deciding factor.

Load Factor—Process equipment can be selected and designed so that it can just handle "par" capacity or so that it has an overload factor. In certain types of equipment this is more important than in others, but it is advisable in all equipment. If the process does not require continuous operation, the equipment should be designed so as to do its job in at least ten per cent less time than is actually required. If the process is continuous, then the equipment should be designed so that it handles the required load at slightly under its actual capacity. This makes for easy operation. It also permits some overloading without crowding the equipment.

Modernization Factor—Equipment may be the last word in modernity when installed, but obsolescence immediately begins its course. Design should therefore include the element of replacement, not so much of the entire system but of component units.

Capital Investment and Depreciation—Regardless of the policy followed by the organization as to depreciation, capital charges and obsolescence, each new process must be carefully studied and rates for these items established from the standpoint of the product, market and process. The rates in the case of one product might be twice the rates in the case of another product.

With these general factors considered and settled, attention is next directed to the actual design and in

Design for the Future

FROM time to time other articles supplementing this design series will appear in *Chem. & Met.* For June two articles are scheduled. One of them is a second article on reaction vessel design written by C. O. Brown and pointed specifically at high pressure vessels. The other deals with the design of plant buildings to fit the process and is written by P. B. Kimball, chief engineer of the Rumford Chemical Works, Rumford, R. I.

this, operation must be constantly kept in mind. Cooperation between the designing engineer and the erecting and operating personnel is of greatest importance. No matter how well designed a piece of equipment is or how perfect it is in the eyes of the designer, if the operators do not like it, it will never attain its full potential efficiency. To this extent equipment is personalized.

The important operating factors in design may be summarized as follows:

Control—From the operator's viewpoint, this is the most important general factor. It is called a general factor because it includes a whole class of items, all of which rank high in importance.

Uniformity of product is directly dependent upon control. Proper control also requires easy starting, smooth operation, simplicity in shutting down the equipment. Automatic control can usually be installed if the equipment is designed for it. It must, however, be properly selected and must be supplemented by manual control.

In both automatic and manual control, too little attention is usually paid to quickness of response of the actuating instrument, in the case of automatic control, or to the indicating instrument in manual control. As an instance, in a spray dryer producing dried skim milk, operation by manual control of the feed liquor gave a product which varied considerably in moisture content. Inspection of the recording thermometer chart showed a change in the temperature of the exit air which could not be smoothed out by hand control. The makers of the indicating and recording thermometers spent considerable time endeavoring to overcome the difficulty without success. A chemical thermometer placed at the same point showed a fluctuation which could be controlled. With the indicating and recording thermometers, there was enough lag so that the system was always over-controlled. Finally a very sensitive thermocouple constructed with small wires—the ends welded together in a small bare spot—was installed, giving almost instantaneous indication. After this, even with manual control a smooth temperature line was obtained.

Control valves are now available in types which aid rather than hinder exact operation. Careful selection of sizes so that the valve is approximately half open at normal operation is advisable. In general, where it is necessary to control liquid flow, metering or positive pressure rotary pumps driven by variable speed drives give much better and more steady regulation than any valve.

If at all possible inspection windows should be provided. There is nothing which helps an operator as much as being able to see what is going on inside of any piece of equipment. Lights can be provided inside or through another window so that inspection can be facilitated. Letting the operator see what is going on inside of equipment oftentimes results in suggestions on his part for improvement and these are generally worthwhile.

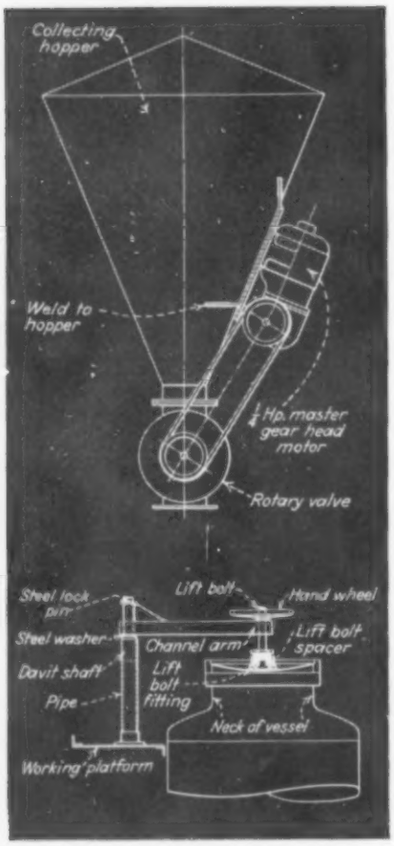
Gages placed at convenient points and so arranged that the lines to them do not clog are of great help in proper operation. Gages are now available made for use with food products and corrosive liquids and gases, the mechanism of the gages being entirely out of contact with the primary actuating fluids.

If starting and shutting down of the equipment is made easy and simple, it is advantageous from an operating point of view. This can be done by design of control and also wherever possible by keeping the amount of material in process at any instant, very small. Thus a certain quintuple effect evaporator handling blank liquor in a paper mill at the rate of 18,000 gal. per hour, has an approximate total of 200 gal. of liquid in the entire equipment at any one instant, control being extremely easy. Starting or stopping is very simple and gives the operator no difficulty.

Foolproofness—Equipment designed to be operated with the minimum amount of brains gives the most satisfactory results. This means not only low labor costs, but also less trouble and a more uniform product and lower maintenance costs.

Cleaning—Almost all equipment has to be cleaned inside at intervals, oftentimes daily. After watching this operation in many instances the writer has wished that the designing engineer might have to operate and clean the equipment. Cleaning of apparatus directly affects both cost and designed capacity, the former because it requires manhours and supplies, the latter because the equipment is not operating while it is being cleaned

Design for operation is the keynote of modern process equipment design. Invariably it is found that the little things which facilitate operation pay dollars-and-cents dividends in the long run. This Pfaudler glass-lined still is installed in a plant of Eli Lilly & Co.



Top — Here the designer has placed the motor, operating a "barrel valve" to discharge powder out of a hopper, in such a place as to be readily accessible and yet out of the way so that the valve itself can be easily opened for cleaning

Above — This davit enables one man to remove a vacuum chamber cover

windows are usually poorly designed. Manholes large enough so that a man can get inside easily and with handholds inside and out so that the operator does not have to depend on a box, step ladder, or chance, are cheap and they will pay dividends.

Valve wheels and control levers should be of such size that they fill the hands comfortably and do not tempt the operator to use a wrench on them.

Convenience—In the case of certain parts of equipment which must be lifted or moved, such as heater or manhole covers, removable connections, etc., it is important to design them with hinges, counterweights and davits so that they can be moved easily by one man. This may seem self-evident, but it is a point frequently overlooked. The weight of these parts must be kept at a minimum or made movable by proper balancing and swinging.

Almost all apparatus has some parts which must be kept tight. Leaks are always costly. Consequently one of the details of design which merits attention is the ease of keeping such parts tight. These points should be perhaps "over designed" without making them cumbersome or their handling time-consuming.

Maintenance—This part of operation includes inspection, adjustment, lubrication, repair and replacement. In many plants the operator takes care of minor maintenance work although this does not as a rule prove satisfactory. Attention on the part of the designer to details will lower maintenance costs.

Studies of the type and material of packing and gaskets are worth while. This is one of the principal "sore spots" in smaller plants.

When designing any apparatus, the entire operation should be discussed with the testing engineer. He may be called upon to run some tests on the system or parts of it. When this happens, the plant may be in continuous operation and he will need to install meters. If provision for making testing connections is built into the apparatus, this work will be greatly facilitated.

In almost every piece of apparatus, there is some part that wears out. Some of these parts are interchangeable, others must be fitted to the job. This merits consideration at the time of design in order to remove as many of the latter as possible.

One might go on and on suggesting refinements in design and citing examples of operations facilitated by forethought on the part of the designer. However, further refinements usually involve specialization and will be left to articles that follow in this section. It may be that a great many of the suggestions made in the present article may appear to the reader as superfluous. But chemical engineering is an operating job—not born in the handbook or on the drafting board. Operation is the ultimate consumer for all design work. Hence equipment should be designed for operation.

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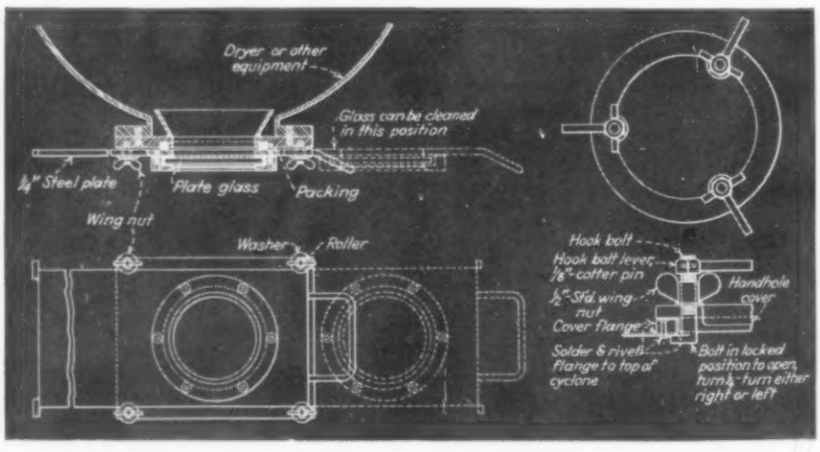
and therefore must be built to produce rated capacity in fewer hours. Cleaning can be minimized and occasionally avoided almost entirely by designing for this purpose. The first cost of equipment is usually higher but the benefits are worth it.

Accessibility—Nothing causes more difficulty in operation than inaccessibility of parts. All parts which the operator must handle or maintenance men must check should be where they can be looked at without too much physical discomfort. Putting things where they can be seen and handled, and selecting pumps on which the stuffing boxes and glands can be seen and which provide ample room for repacking, are essential. Trouble with equipment is avoided when it can be kept in good condition easily.

Manholes and inspection doors and

Left — An observation window on a spray dryer is designed in such a way that it may be slid to one side and cleaned after the thumb screws have been loosened. Without this feature the glass would quickly be rendered useless

Right — An improved handhole cover with detail showing latchbolt construction



Influences on Choice of Materials

BY GEORGE K. HERZOG, Electro Metallurgical Co., New York. After having received his early training under the direction of Prof. J. W. Richards and Charles M. Hall it is not surprising that the author has devoted his thoughts and energies to metals, their manufacture and applications for over 30 years.

DESIGN FOR OPERATION

GOOD DESIGN of equipment involves much more than the thought given to drawing board details. A knowledge of the process for which the equipment is designed, the properties of all possible usable materials, their prices, fabrication costs—all this information must be considered. It is well, too, for the designer to know how well established the process is, in order that he can determine whether higher-priced, longer-lived materials can be used without danger of premature obsolescence.

Much of these data may be obtained from standard handbooks and suppliers' catalogs. Engineering and research staffs in the larger companies may also provide a good share of the necessary information. But new materials and modifications of old materials are being developed so rapidly that even with all these facilities it is often difficult to keep abreast of latest developments.

Designing Depends on the Process

When a designer is confronted with the design of a new piece of equipment for a well-established, standard process, his problem is relatively simple. Experience has demonstrated what materials are satisfactory and unless a new situation has arisen, such as, for example, a demand for a purer product, the material which has proved satisfactory for past service will usually be chosen. However, this is not always the best procedure. It is not only possible but quite likely that materials are available now that were not available when the original equipment was installed. In order to make sure that he has all the pertinent data, the designer should review the latest developments in various materials to determine whether or not any of them might meet his requirements better than the materials that were used in the past. If he has access to an engineering staff or research laboratory, or if his firm maintains a materials engineer, he can usually obtain all of the data he needs or at least he can be reasonably sure that he has not overlooked any outstandingly good material.

When equipment is to be designed for new processes, or when changes are to be made in equipment to meet a new set of conditions for old processes, the problem becomes much more complex. Sometimes the development of the process has advanced to the point where a pilot plant with equipment of semi-commercial size can be operated for a reasonably long time before the design of a full-size plant must be undertaken. The experience gained in the design, construction, and operation of such a pilot plant is of greatest possible help in determining the most suitable materials for constructing a full-sized process plant. In many cases the design engineer, even though he has considerable experience on which to base his design and can get additional data from the materials department or other departments of his own organization, will find it highly desirable to obtain the advice of the engineers and metallurgists of manufacturers supplying the various materials which he wishes to consider. The technical departments of firms such as ferro-alloy manufacturers also frequently have pertinent data available. The producers of the metals and ferro-alloys used in the manufacture of steel and other alloys nearly all maintain staffs of engineers and metallurgists whose duty it is to keep abreast of the latest developments in their lines and who are continually working on the production of new and improved alloys. The data and experience collected by these organizations are available to the designer without cost or obligation of any kind.

Full Details Are Needed

The following discussion of the problems of design as they relate to materials of construction is confined mainly to steels, especially those of the heat- and corrosion-resistant type, but it applies equally well to all materials of construction. It seems obvious that, in order to be able to recommend the material best suited for any piece of equipment, all conditions under which it is to be used must be known. No attempt will be made to show the type of material best suited for any specific purpose. Rather, examples will be cited to indicate why full details of the process should be disclosed, insofar as this is possible, when recommendations for the material are desired.

In asking for materials data, the designer should describe the general nature of the process, and should state whether it is intermittent or continuous. In an intermittent or batch process there is usually less chance that some unsuspectedly harmful material will be introduced from other equipment in the circuit; and there is, of course, much less danger of corrosion due to dissimilar materials being in contact or close proximity to each other.

It is important that the size of the equipment or apparatus be given. A material entirely suitable for a small piece of equipment is often not at all satisfactory for large units. As a matter of fact, one of the greatest problems encountered is the selection of suitable materials for the large commercial operation of a process which had been proved sound when it was

conducted on a laboratory or even on a pilot plant scale. Size is frequently the major factor in determining the most suitable grade of corrosion-resistant steel. For example, tests may have shown that a standard grade of annealed 18 per cent chromium, 8 per cent nickel steel fulfills all mechanical and chemical requirements. If the equipment to be built is of such a size and shape that it can be safely heated to 1,100 deg. C. and rapidly cooled, this grade of steel would prove entirely satisfactory. If, on the other hand, the equipment is to be so large or the shape is such that it cannot be heat-treated in this manner, it would be necessary to use the chromium-nickel steel stabilized (i.e., made immune to intergranular corrosion) by columbium or titanium.

Impurities Should Not Be Overlooked

It is important to state whether or not a slight discoloration of the product is permissible. In many cases a material may be entirely satisfactory from the standpoint of equipment that will have long service life but will not be suitable because it discolors or otherwise slightly contaminates the products. The use of steels of slightly modified composition is frequently all that is necessary to give entirely satisfactory service. For example, a plain 18-8 chromium-nickel steel may satisfactorily withstand the action of concentrated acetic acid insofar as life of equipment is concerned but may cause a slight discoloration which is objectionable. The molybdenum-bearing 18-8 steel, on the other hand, is entirely satisfactory.

The nature of the material to be handled, and the conditions under which it is to be handled, are obviously of great importance in determining the type of construction materials that can be used. Whenever possible, materials being considered should be tested under exactly the same conditions as those of actual operation. This is not always possible, but the designer when asking for data from outside sources should be careful to give all possible details.

It is not always sufficient to know merely the approximate composition of material to be handled. Its exact composition must be known if an intelligent selection is to be made. The presence of very small amounts of impurities frequently has a marked effect on the corrosive action of certain materials. Sometimes these act as inhibitors, at other times as accelerators of corrosion.

The presence or absence of air in a solution may readily be the factor determining the choice of a material.

A knowledge of the temperature and pressure of operation is important for many reasons. Knowledge of the exact operating temperature plays an important role in determining the rate at which the substances being processed will attack the equipment. Some substances will attack the structural materials of the containers at rates which vary more or less directly as the temperature; others are apt to attack them but slightly at one temperature and attack them rapidly at temperatures only a few degrees higher.

Of great importance is the actual strength of the material at operating temperatures. Where it is necessary that the original dimensions be maintained, the creep strength of the material at operating temperatures must be such that the increase in size is within the allowable limits.

In the case of some alloy steels the operating temperature is of further importance in that the steels suffer deterioration when held for long periods of time within certain temperature ranges. An example of this is the intergranular deterioration of the austenitic chromium-nickel steels when held within the temperature range of 425 to 870 deg. C. If the operating temperature is within this range or if the manufacturing cycle is such that the equipment stays within this range for a substantial length of time, the plain or unstabilized 18-8 stainless steel will not give satisfactory service, particularly if corrosion is also a factor. However, a steel of this type stabilized by titanium or columbium, preferably columbium, can be safely used. Some of the plain chromium steels containing in excess of about 15 per cent chromium tend to develop a coarse grain structure and consequent brittleness when held for a long time at temperatures above about 1,000 deg. C. This tendency is to a large extent suppressed by the addition of a small amount of nitrogen. These steels also develop brittleness at room temperature after they have been held for a long time at a temperature of 400 to 500 deg. C. This can, however, be overcome readily by heating the steel to a red heat and then cooling it rapidly through this temperature range.

The 4 to 6 per cent chromium steels, widely used in the petroleum industry, are subject to temper embrittlement when cooled slowly through the temperature range of 400 to 600 deg. C. This brittleness does not exist at the operating temperature nor in the temperature range that causes it, but is evidenced at room temperature. This type of embrittlement is entirely eliminated by the addition of about 0.50 per cent molybdenum.

Even the molybdenum-bearing steels of this type are subject to another form of embrittlement when exposed to certain operating temperatures. Exposure to these temperatures causes a marked decrease in impact strength, not at operating temperatures nor even at room temperature, but at subzero temperatures. This is of importance in only a limited number of applications where the equipment may be subject to shock at extremely low temperatures but it should nevertheless be kept in mind. This difficulty can be entirely avoided by using a 4 to 6 per cent chromium steel containing both molybdenum and columbium.

The design of equipment for extremely low temperatures usually involves primarily the selection of a material having, at operating temperature, suitable mechanical properties which are not adversely affected at these low temperatures. Usually the final choice is made on the basis of cost and ease of fabrication. Several of the materials having excellent low-temperature properties are relatively high priced, and considerable successful work has been done in the development of the lower-alloy steels suitable for this type of application.

Temperature Cycle Also Important

The temperature cycle through which the equipment passes is of the utmost importance in selecting a suitable material. Not only is the temperature of operation important but also the rate at which it changes. It is well known that sudden temperature changes are apt to crack brittle materials, but it is not so well recognized that slow changes through certain temperature ranges may also have an adverse effect. As has already been shown, the unstabilized corrosion-resistant steels of the 18 per cent chromium, 8 per cent nickel type are adversely affected when cooled slowly through the temperature range of 425 to 870 deg. C., and that the plain 4 to 6 per cent chromium steels are subject to temper embrittlement when cooled slowly through the range 400 to 600 deg. C. Sometimes there is a wide difference in temperature be-

tween various parts of a piece of equipment and this, too, may lead to trouble. For example, a plain 18-8 chromium-nickel steel will stand up indefinitely in an atmosphere containing substantial percentages of sulphur dioxide with small amounts of sulphur trioxide as long as the temperature is high enough to prevent condensation. However, if condensation occurs, the sulphuric acid will attack the steel, particularly at points where the temperature rises after the condensation enough to evaporate the water and thus concentrate the acid. If, in addition, the gases contain hydrocarbons which condense at the lower temperature, or contain particles of soot which are caught by the condensate, matters are still further aggravated. Sometimes these difficulties can be avoided by suitable changes in design, but at other times they call for the choice of a different material.

Many more examples could be cited to show the importance of knowing the full temperature cycle through which the equipment will pass. The above examples have been chosen mainly because they illustrate the type of information which the designer might not have available, and which cannot be developed by either laboratory experimentation or even short time operation of a pilot plant, but which may be of the utmost importance in the design of equipment.

It is generally appreciated that the pressure at which a piece of equipment must operate is of extreme importance when high-pressure processes are under consideration, but it is not so generally known that even a moderate increase over atmospheric pressure may be of importance where corrosion is concerned. Thus it has been found in one newly developed process that, at a pressure of 60 lb. per sq. in., corrosion of a plain 18-8 steel is 30 times as great as at atmospheric pressure.

Where both high pressure and high temperature are encountered, the choice of material must be based largely on experience. It is easy enough to design the equipment so that it will be amply safe at operating temperatures if one can only be sure that the materials will not deteriorate under operating conditions. It is, however, never safe to assume that this is the case. Hydrogen at ordinary temperatures and low pressures has little or no effect on plain carbon steel. On the other hand, at high temperatures, and pressures such as are used in ammonia synthesis and in various hydrogenation processes, the hydrogen will react with the carbon of the steel and decarburize and greatly weaken it unless the carbon is present in the form of stable carbides such as those of chromium, vanadium, and molybdenum.

Tank lined with nickel sheets. Constructed with Smithlining, sheets are automatically spot-welded

Just as the presence of hydrogen will decarburize a steel under some conditions so does the presence of hydrocarbons cause a carburization of steel under somewhat similar conditions. The steel best suited for a process using gases containing hydrogen at some particular pressure and temperature would not be the most suitable steel for a process in which hydrocarbon gases are present at the same temperature and pressure.

Both hydrogen and hydrocarbons are good reducing agents, and atmospheres containing them in substantial amounts would be of a reducing nature. When oxidizing gases are present the situation is again changed and the most satisfactory steel would be of a different analysis. In general, the high-chromium steels give much the best service under oxidizing conditions. Under certain conditions, as when substantial amounts of sulphur are present, the plain chromium steels give superior service. This is, however, not always the case and at the highest operating temperatures used the high nickel-chromium alloys are preferred. Again, for many applications the high chromium-nickel steels are preferred to the plain high-chromium steels because the former are somewhat easier to fabricate.

Manufacturers of non-ferrous condenser and heat exchanger tubes have found that under some conditions, the velocity of the liquids passing through a tube has a pronounced effect on the life of the tubes. Below a certain critical velocity the life of the tubes is entirely satisfactory; above this velocity they fail rapidly.

When two pieces of a metal or alloy slide over each other, there is often a tendency for them to seize or gall. In some cases this difficulty may be overcome simply by making one of the pieces slightly harder than the other. In other cases it is better to use dissimilar alloys.

There is no alloy steel that is better suited for heavy crushing and grinding machinery which is to be subjected to severe abrasion and shock, such as in rock crushing, than the standard Hadfield manganese steel. One would expect that if it is so satisfactory for severe service, it would be even better for light service, but such is not the case. This steel needs severe working of the surface in order to develop hardness, and when conditions are not severe, the surface wears away before it has a chance to harden. For such service,

as in the crushing of friable materials, a modified composition containing chromium gives better results because it imparts greater initial hardness to the parts and reduces the work required to develop the surface hardness.

In crushing and grinding operations where abrasion is severe and mechanical requirements relatively moderate, alloys such as one containing 25 to 30 per cent of chromium and 2.50 per cent of carbon, and a cast iron containing about 4.5 per cent of nickel and 1.5 per cent of chromium give outstanding service. For service in which a combination of good resistance to wear and to mechanical stresses is required, a number of low-alloy heat-treated steels—among which one containing about 3.5 per cent of chromium is prominent—give good results.

Whether a solid material or a so-called clad material should be used depends again on many things. In general, there is only one advantage in using clad material in place of the solid—and that is lower cost. The cost of the clad material is usually substantially lower than that of solid material of the same strength, particularly in the heavier sizes, but in many cases there are fabricating difficulties which counter-balance to a greater or less extent the savings due to lower material cost. Certainly clad material should not be used without giving serious thought to possible disadvantages as well as to the savings in material costs. Whether a material with a protective coating, such as glass or a sprayed or electrodeposited coating, should be considered also depends on many factors. No intelligent recommendation can be made unless all the conditions of service are known.

Fabrication Affects Serviceability

One of the most important factors to consider in selecting a material is its workability. Today a large part of equipment is of welded construction, and it is almost essential that the material chosen, if a metal, be readily weldable. Unless the welding properties of a material are known, it is well to make sure that the material can be welded not only in the construction shop where there are facilities for handling the equipment and for heat-treating it if this is necessary, but also after it has been installed, if repairs should become necessary.

The effect of the fabrication operations on the properties of the material are often of the utmost importance. Thus a sample of, say, a straight 18-8 chromium-nickel might be satisfactory in laboratory corrosion tests or even when subjected to the actual conditions under which it is to operate, yet fail in service simply because the cold-working during fabrication has so changed its resistance to corrosion that it is no longer satisfactory. A slight modification of the composition might be all that is necessary to obviate this difficulty; or if heat-treatment is possible, this, too, would be effective.

There is always danger of electrolytic corrosion when dissimilar metals are used in the same piece of apparatus, but as it is often impossible to avoid this type of construction, the only thing to do is to take the proper precautions to minimize danger from this source. The metallurgist can often be of help with problems of this nature.

There are many other cases where some easily overlooked detail of construction or operation has an important bearing on the choice of material. It is hoped, however, that enough has been said to convince the designer that the more information he can give about the process, the more helpful the metallurgist or engineer whom he is consulting can be in this co-operative determining of the best material for the equipment.

How to Find Materials Information

THE EDITORS have gathered together the sources of information that will give the engineer the pertinent facts needed in order to select the proper materials for his specialized requirements

DESIGN FOR OPERATION

IT FREQUENTLY HAPPENS that a chemical engineer requires detailed information about some one or more of the factors influencing the selection of a material or materials. It may be that he finds it necessary to investigate the effects of using two dissimilar metals in contact with one another, or the effect of high temperatures or pressures on certain materials. He may have a problem in handling an abrasive chemical or one that is both abrasive and corrosive. Sprayed metal coatings, synthetic resin base protective coatings, or linings of special alloys, may call for attention. To discuss each one of these and the many other factors affecting the choice of materials for the construction of equipment at sufficient length to be of value to the engineer would require far more space than is available. Therefore, he will be referred to sources where these various subjects are treated in much detail.

A group of articles on metallic and non-metallic materials of construction with the purpose of supplying the chemical engineer with the pertinent information he needs in order to select the proper material for his specialized requirements was included in the Eighth Materials of Construction Number, of *Chem. & Met.*, Vol. 45, November, 1938. These articles, each dealing with a closely related group of materials, discuss the advantages and limitatons, with regard to fabricating characteristics, forms in which available, costs where significant and special properties such as resistance to corrosion, heat and abrasion. With this knowledge the chemical engineer should be able to make at least a preliminary selection of the materials and to work more intelligently with the equipment manufacturer in securing proper design and fabrication.

One of these articles, Abrasion Resistant Alloys, p. 587, covers the problem of selection of materials to combat excessive wear of equipment due to grinding, crushing, and to a lesser extent to the action of sludge. Abrasive action can be combated by the use of any one of several types of resistant materials. Among the most important are: the metal that is hard throughout, an ordinary metal whose surface is hardened, and an ordinary metal which is covered with a layer of about $\frac{1}{8}$ in. of hard surfacing material.

Several of these articles deal with the non-metallic materials, rubber, chemical stoneware, glass, glass linings, fused silica, carbon and graph-

ite, wood, and plastics. The engineer will probably find more information about the non-metallic materials in this source than anywhere else.

The typical article, in a concise manner, presents the fundamental considerations involved in the selection and utilization of the group of materials covered. The recent developments are brought to the attention of the engineer. The characteristics of every member of the group are given and compared. The standard forms and sizes in which each one is supplied are listed. The method of installation is described where essential, such as in the case of synthetic resin pipe which requires special handling in order to prevent injury. Fabrication methods are discussed.

Prices of Alloy Steels

When several materials are of equal suitability from all other considerations the engineer naturally chooses the one that is obtainable at the lowest cost. For the purpose of assisting in the selection, the current prices of some of the alloy steels are given in tabular form on page 651 of the issue mentioned. While these prices may change from time to time it is probable that their relation, one to another, will continue.

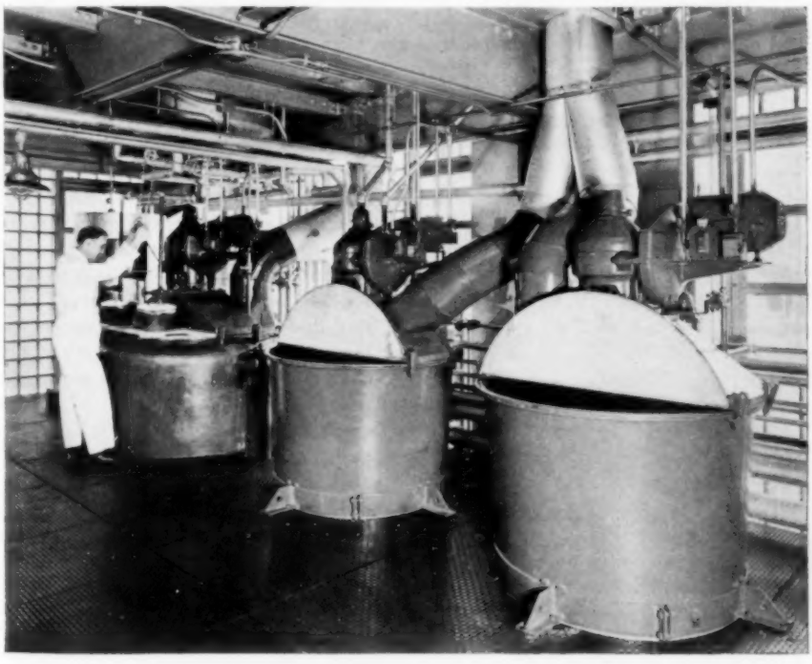
The second part of this issue presents in compact form worthwhile data on chemical, physical and mechanical properties, available forms, name of manufacturer, trade name, etc., for each of about 800 metallic and non-metallic materials.

Corrosion data for the most generally used mineral acids, alkalis and other chemicals are given for 117 metals and alloys in an insert in *Chem. & Met.*, Vol. 36, No. 9. The metal manufacturers' recommendations for the use of each product in various chemicals at several concentrations and temperatures are given. In some cases the corrosion rate in inches penetration per year is given, which is extremely valuable to the designer of equipment. The resistances of these metals to chlorine, sulphur dioxide and other industrial gases at high temperatures are also listed.

The chemical manufacturers give their experience regarding the most satisfactory materials of construction for the various pieces of equipment used for handling and producing over 60 chemicals in a supplement to *Chem. & Met.*, Vol. 41, October, 1934. These experiences are amplified in a series of articles, prepared by chemical engineers in the process industries, in the same issue.

The most economical means of extending the life of equipment is sometimes questionable. In some cases increased thickness of metal is used while in others protective coatings are added from time to time. The several methods are discussed and compared in an article, Is Increased Thickness of Steel the Answer? by D. Gutleben, *Chem. & Met.*, Vol. 45, pp. 136–138. During the last 13 years that the fermenters in an alcohol distillery have been in use much data on the rate of corrosion, as well as the costs and increased life by metal spraying, painting and other methods of maintenance have been accumulated. This information, which is presented in tabular form, was used in designing the fermenters that replaced the original installations.

Glass-lined still and solutions tanks for the preparation of ethyl mecuric chloride in the Eli Lilly & Co. plant



Non-ferrous Metals

The corrosion behavior of specific metal and alloy groups are treated in the book, "Corrosion Resistance of Metals and Alloys," by McKay and Worthington, 1936, Reinhold. Among the chapter subjects are: magnesium and its alloys, aluminum and its alloys, zinc and zinc coatings, cadmium plate, lead, iron and steel, chromium alloys, chromium plate. The non-ferrous metals have received most attention.

In the first part of "Corrosion—Causes and Prevention" by F. N. Speller, 1935, McGraw-Hill, the facts and factors already known are described together with the generally accepted electrochemical theory of corrosion, leading up to a system of classification of corrosion phenomena and the principles of corrosion testing.

In the second part will be found a discussion of the practical application of the facts and principles already established with reference to corrosion prevention under the conditions found in the air, under water, under ground in closed water systems, steam boilers in the chemical industries and in other situations. This involves a choice between using a more durable metal, a suitable protective coating, or, in certain cases, conditioning the corroding agent so that it will form a natural protective coating or be less active toward the metal. The contents have been written with particular reference to the ferrous metals.

In "Metallic Corrosion, Passivity and Protection," by Ulick R. Evans, 1937, Arnold, the engineer will find the chapters of interest that deal with: oxidation at high temperatures, corrosion by stagnant liquids, corrosion by moving liquids, influence of stress and strain, protection by metallic coatings, and protection by paints and enamels.

Clad and Lined Equipment

BY F. P. HUSTON, Research and Development Division, International Nickel Co., New York, has been associated closely with the development of clad and lined materials during the past ten years. His interests have included not only production problems but fabrication as well.

DESIGN FOR OPERATION

THE CHOICE OF A MATERIAL for the construction of a piece of equipment involves, generally, a number of factors. An extremely important factor in many cases in the chemical process industry, as judged from the tonnages now in use, is purity of product. This is an important thing that is difficult to evaluate closely in terms of dollars and cents. Another important factor is the economy resulting from the longer life obtained by the use of cladding or lining materials that are more resistant than steel, or other foundation materials, to corrosion.

Lining materials are not intended to be used under severe corrosion conditions that would penetrate the lining in a relatively short period of service. A safe rule to follow is to limit the use of lining materials, except in special cases, to services where the average corrosion rate does not exceed 0.005 in. penetration per year. The corrosion rate in most applications where lining materials are now used, is considerably less than 0.005 in. penetration per year.

The use of base materials that have a low resistance to corrosion by the contents of a lined vessel, should be avoided, unless proper precautions are taken to insure removal of the vessel from service in the event of failure of the lining before the vessel is made unsafe through corrosion of the base or supporting plate. Such applications cannot be permitted in the ASME or API-ASME code vessels for general use, but may be permitted in special cases where adequate inspection during service, is assured. A typical example is in the extensive use of the Types 410 (10-13.5 chrome, 0.12 max. carbon) and 304 (18 chrome, 8 nickel, 0.08 max. carbon) stainless steels in lining steel petroleum refinery vessels. The resistance of these materials to "dry" corrosion by the oils and vapors at elevated temperatures affords complete protection to the steel base material. Frequent periodic inspection is, however, necessary to insure against the relatively rapid corrosion of the steel should a failure of the lining occur.

Extensive use has been made of thin sheets of corrosion-resisting metals and alloys as loose linings in steel and wood tanks, with satisfactory results where their use has been confined to relatively small tanks for storage and the like. Various means are used for joining depending upon the gage of the lining, the size and shape of the vessel, and the corrosion-resisting requirements of the joint. The most commonly used methods are: (1) lock-seamed and soft-soldered, (2) lock-seamed and silver-brazed, and (3) welded.

Lock-seamed and soft-soldered joints are used in lining relatively small vessels with copper, Monel, and similar materials which are readily soft-soldered. The gages used are generally about 0.031 in. or thinner. The soft-soldered joint is mechanically weak and its use must be avoided in vessels in which the joints are subjected to stresses due to thermal expansion or to excessive vibration. Soft solder has, generally, a low resistance to corrosion, and in most cases is anodic to copper or Monel, which causes accelerated corrosion of the solder through galvanic action. Its dark appearance may also be objectionable in some cases.

Silver-brazing has a wider range of adaptability than soft-soldering for most applications where corrosion-resistance and strength are factors. It may be used with Monel, nickel, stainless steel, and Inconel. The silver-brazing alloy is cathodic to nickel and the high-nickel alloys in most media, and hence is protected galvanically. A high degree of skill is required to apply silver-brazing to avoid excessive buckling, which may be troublesome particularly with thin linings.

Welding is, generally, the preferred means of joining loose sheet linings because of the high strength and corrosion-resistance of the joints. The method of welding and the type of joint will depend largely upon the gage of the sheet. The metals and alloys most commonly used as welded loose linings are Monel, stainless steel, aluminum, and silicon bronzes. The most favorable gage usually is 0.062 in., though linings in gages as thin as 0.031 in. can be welded by operators skillful in the welding of thin sheet materials.

So many factors are involved in applying loose linings by welding that no attempt will be made here to discuss welding.

Linings in massive equipment, pressure and vacuum vessels, dryers, and other types of equipment subjected to mechanical and thermal stresses, must be securely welded or bonded to the supporting vessel to provide against failures from buckling due to temperature changes, collapse due to vacuum, or other mechanical causes. The logical approach to this problem has been made by applying the metal or alloy as a cladding or covering to suitable base materials, usually steel.

The introduction of nickel-clad steel the latter part of 1929, and the development of a process of resistance welding alloy sheets to steel plate at about the same time, made available means to conserve the more

expensive materials and permit the construction of vessels with linings of corrosion-resisting metals and alloys adequately secured to any required thickness of steel plate. Then followed the successful production of clad and covered plates by other methods. With improvements in weld rods and techniques for fusion welding, and the introduction of portable, gun-type resistance welders, the successful installation of sheets as linings in existing pressure vessels has been made practicable.

Nickel-, Monel-, Inconel-, and stainless steel-clad plates are available in sizes comparable to steel plate, which enables the construction of large vessels. Claddings offered in stainless steel include the chrome-nickel steels, Types 306, 308, 321, and 347, and the straight chrome steels in Types 410, 430, 442, and 446 (for composition of these alloys see *Chem. & Met.* Vol 45, p. 651, 1938).

Nickel-, Monel-, and Inconel-clad plates are supplied in standard thicknesses of cladding of 5, 10, 15 and 20 per cent. For example, the thickness of the cladding on a ½ in. plate, clad 10 per cent, is 0.050 in. The 5 per cent cladding is produced only on plate ½ in. tnick or heavier.

The standard thickness of cladding on the stainless-clad plates is 20 per cent, though other thicknesses may be obtained.

The cladding process used lends itself to the bonding of the metal or alloy on any quality of steel plate now used or apt to be used for pressure vessels. Flange quality steel, of 55,000 lb. per sq.in. minimum tensile strength, is the standard used on the regular quality plate and, to date, no other quality of base steel has been found of advantage. However, if the need arises for higher strengths, such plate could be supplied.

Nickel, Monel, Inconel, and the stainless steels, all being of higher strength than flange quality steel, increase the strength of the composite plate over that of a steel plate of the same thickness.

The results of tests made on nickel-clad steel plate, shown in the table, are from test coupons taken from random rollings and are specific tests not intended to represent maximum or minimum values.

Flange quality steel of 55,000 lb. per sq.in. minimum tensile strength was the base plate used in each of the above coupons. The thickness of the cladding was 10 per cent.

As nickel has the lowest strength of the group of materials now supplied as claddings on heavy plate, the increase in strength obtained with Monel, Inconel, and the stainless steels, is greater.

Physical Properties of "As Rolled" Nickel-Clad Steel Plate

Gage	Yield Point per Sq. In.	Ultimate Tensile Strength per Sq. In.	Per Cent Elongation in 8 In.	Per Cent Reduction of Area
$\frac{3}{8}$ in.	36,800	64,900	27.0	56.7
$\frac{1}{4}$	43,500	63,300	27.0	53.2
$\frac{5}{16}$	40,500	63,200	27.0	60.6
$\frac{3}{8}$	37,200	62,000	30.5	59.1

The bond at the interface in clad steel plate produced, under proper conditions, by pressure welding, is found to be stronger than the steel.

The maintenance of a continuous surface in the clad lining is, essentially, the only problem new in the design of pressure and vacuum vessels and other types of equipment fabricated from clad plate.

Pending the inclusion in the ASME Code for Unfired Pressure Vessels of material specifications and rules governing the use of the clad materials, the designer should apply the formulas, joint efficiencies, and working stress allowances as written for steel. The thickness of the plate, as determined by the safe allowable working stress, may be the thickness of the composite plate including the thickness of the cladding, unless otherwise specified.

Clad fabrications require no special treatments other than adherence to the careful procedures required to insure properly welded joints, which is actually a requirement no different from that required in welding a structure in any material. The treatment required for the stainless-clad materials is determined by the treatment required for the type of stainless alloy used in the cladding. If the corrosive conditions of service require the stainless alloy to be cooled rapidly from a high temperature to re-dissolve carbides, this treatment must be given the clad vessels.

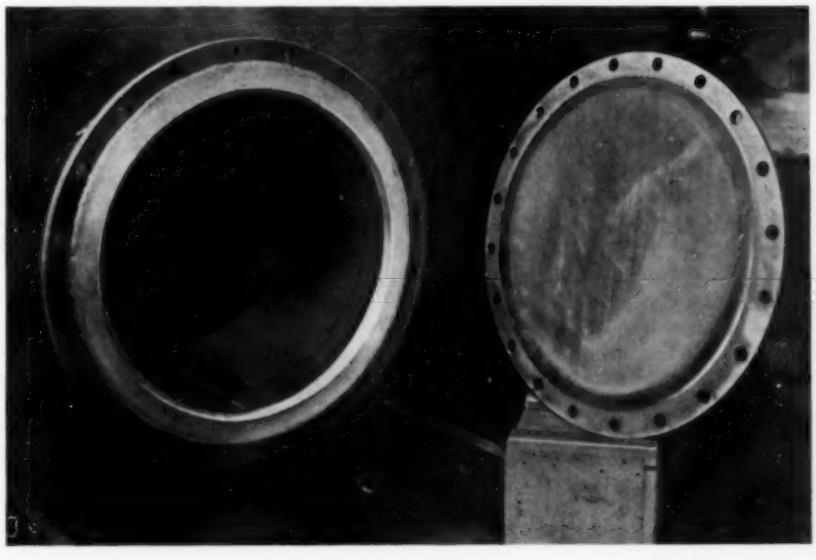
Nickel-clad steel is permitted for the construction of Code vessels on case rulings. The ASME Code Committee, in their Case No. 828, has permitted the use of nickel-clad plate, but the allowable working pressure is computed from the thickness of the steel base plate. Welding tests are called for in accordance with the Class requirements in each case.

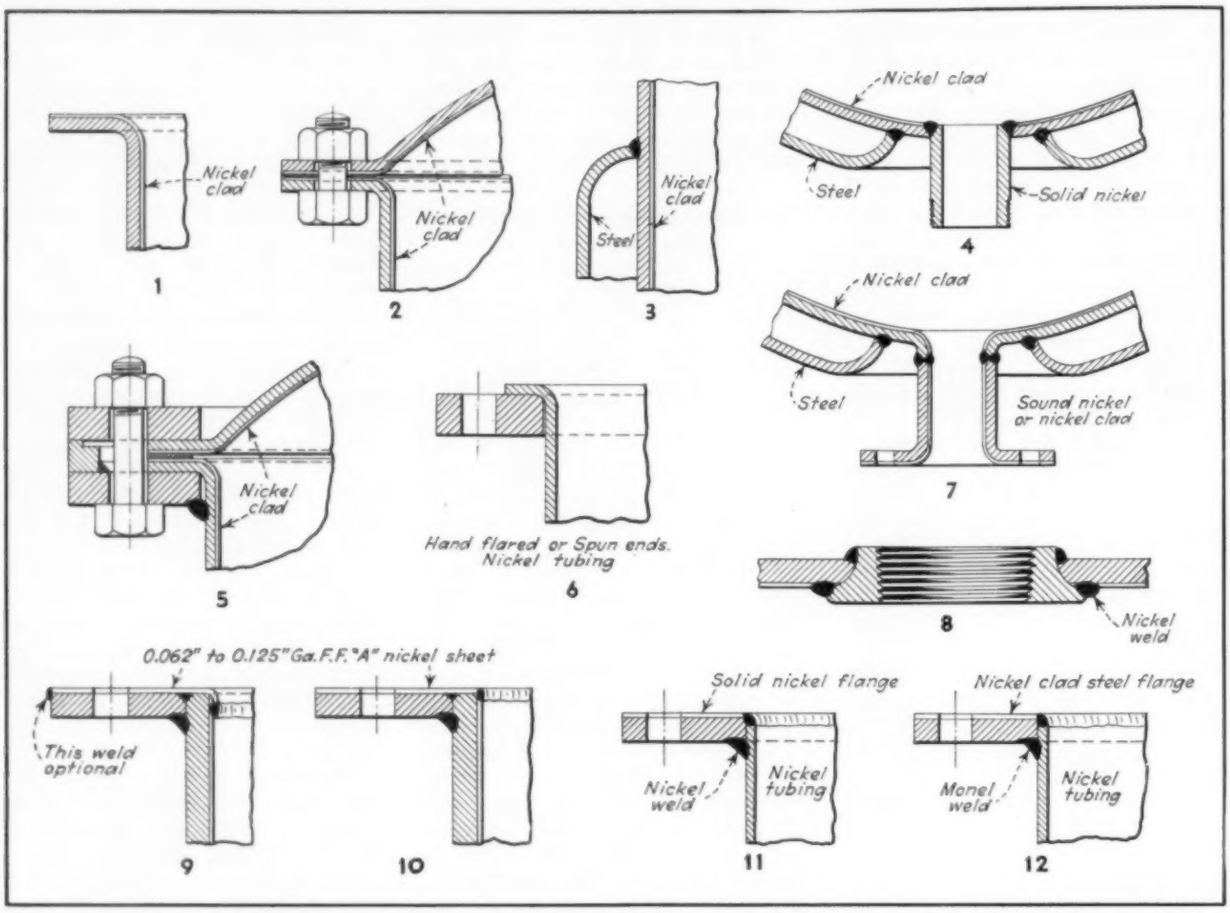
This ruling has been found to be readily workable and has imposed no hardships other than the need for producing plates in odd gages.

The importance to be placed upon the design of the joints, and requirements for adhering to proven practices in welding, cannot be overemphasized.

Contamination of the weld metal on the clad side with iron from the base plate, is a factor that depends upon the design of the joint and the welding procedure followed. While

Manhole cover ⅜ in. ten per cent nickel-clad steel. It is in a petroleum refinery still





1 shows top reinforcing curbs for open vessels in lighter plate gages. Methods shown in 2 and 5 may be used for flared and dished cover plates on vessels that operate under pressure or vacuum. Jackets are readily welded to nickel-clad vessels as in 3, 4, and 7. Forged, tapped welded flanges in solid nickel up to 4in. IPS are available and may be applied as in 8. Built-up flanged fittings, 11 and 12, or loose flanges, 6 are suitable for outlets to 6in. IPS. 9 and 10 show suitable designs for large outlets and manholes

for most applications of non-ferrous claddings the presence in the weld metal of as much as 20 to 25 per cent of iron does not appreciably affect the resistance to corrosion, rather stringent specifications are made sometimes limiting the iron content to unnecessarily and unattainably low values. For specification purposes, an iron content of 15 per cent maximum, has been found to be satisfactory by both fabricator and user for most of the purposes for which nickel-clad steel has been used. In special cases a lower iron limit may be desired and can be attained by special and more expensive joining methods.

The problem is somewhat different with stainless steel-clad plate, as weld rods are obtainable having lower iron than the cladding alloy, and hence the pick-up of iron from the base plate can be compensated for by the higher alloy content of the weld rod. For example, stainless steel claddings of approximately 18 per cent chromium and 8 per cent nickel, may be welded with 25-12 or 25-20 weld rods.

A beveled butt joint should be used whenever the nature of the work allows. Field erection of large storage tanks may require a lap joint. A modification of the joint to include the fitting of a narrow strip of the same composition as the cladding, to cover the exposed edge of the steel, and welded with two beads, is preferred by some fabricators.

The distinction drawn here between lined pressure vessels and clad pressure vessels is that by lined vessels is meant linings applied by attaching sheets either by resistance or fusion welding to flat steel base plates prior to fabrication of vessels, or to existing vessels; while by clad vessels is meant vessels fabricated from flat plates clad by pressure welding and hot rolling.

Linings may be applied in wide sheets securely welded to the steel along the edges, and secured with properly spaced plug or resistance welds, or in strips of a suitable width not requiring the use of intermediate anchorages.

The use of linings installed in the above manner has not developed in any large degree, except in the petroleum refinery field, in applying liners of stainless steel and Monel. The method has not been applied generally in the chemical field, but it seems worthy of consideration, especially for use in equipment such as tank cars and the like. A notable case is the lining with nickel sheets of the cargo tanks of a large tanker employed for the transportation of liquid caustic soda and other commodities.

Design of Equipment Details

BY C. O. SANDSTROM, owner of the Thermal Engineering Co., Los Angeles, and consultant on equipment design problems. More than 30 years of broad engineering experience furnishes the background for the numerous design articles previously published by this writer in Chem. & Met. *The present article reduces mechanical design principles to their fundamentals.*

DESIGN FOR OPERATION

ALTHOUGH MATHEMATICS is a highly useful tool in the hands of the engineer and designer, the layman would be astonished at the amount of engineering that is being accomplished successfully with the aid of the merest rudiments of the science. This is a fortunate circumstance, since comparatively few engineers are skilled mathematicians. Furthermore, few of the great inventors have been skilled mathematicians and in fact, some of them have expressed contempt for mathematics and mathematicians. Convenient as full use of it would have been, mathematics apparently has not been essential to most of the progress we have known. Even when an idea has been developed by sheer reasoning, the results cannot be accepted until tested in that universal solvent, Experience.

Methods in higher mathematics are necessarily complex, and although mathematicians have made commendable efforts to simplify their science, empirical formulas based on experience are still largely used in engineering. When faced with a choice between spending an extra dollar on material, or $10 worth of time on a series of equations bristling with Greek letters, the engineer appears to be wise to choose the former.

In this article we shall present a number of formulas for the design of familiar details of chemical plant. The methods, although not always exact or in agreement with the more highly mathematical methods introduced in recent years, have, however, proved satisfactory in that the equipment "stood up" for the duration of its economic life. Supplementing the formulas are comments that appear needful.

The forces dealt with in the design of chemical plant and structures are tension, compression and shear, singly or combined. Forces produced by acceleration seldom enter the picture so will not be considered. What to add to the thickness of parts to allow for corrosion, erosion or deterioration must be decided for each particular case from a study of the working conditions.

The simplest force encountered is the one producing *tension* which, if applied along a line passing through the centroid of the section, produces tensile stress regardless of the length of the member. The same is true for *compression;* but for long lengths the slightest shift of the line of the applied force may produce bending, and for that reason we have formulas that take length into account. The tendency of an object to be sheared or cut along a plane parallel to the forces acting on the object is *shear* and the stresses these forces set up are shearing stresses. Shear uninfluenced by tension or compression is found in helical springs and in portions of rotating elements such as line-shafting that transmit energy, but do not carry pulleys or gears that introduce bending stresses. The shear in beams is always influenced by tension and compression, and is therefore modified by these forces.

In Fig. 1 are members in tension and compression. If the forces P are truly axial the stress is $s = P/A$, in which A is the cross-sectional area of the member.

In Fig. 2 the lines of action of the forces P do not coincide with the centroids of the sections and we have the eccentricity e. The maximum stress is then in the outer fibers and may be either tensile or compressive, as determined by the formula for extreme fiber stress under eccentric loading. This formula is $f = (P/A) \pm M/Z$ or $f = P/A \pm Pe/Z$, where M is the moment, or the product of P and e, in inch- or foot-pounds, and Z the section modulus of the area. This last factor will be described later. If P acts along a line one-sixth the transverse dimension from the centroid of a rectangular piece, the stress $f = 2P/A$, or double the direct stress. As e approaches $b/2$, f approaches $4P/A$. For a circular section, the line of action of P need be eccentric only one-eighth the diameter to double the stress. Unrecognized eccentric loading is one of the things that make factors of safety absolutely necessary. Structures have frequently failed because of it.

Moment (Fig. 3) is defined as the tendency of a force to produce rotation, and is measured by the product of P and the perpendicular distance of its line of action from the center at which the rotation tendency is to be computed. The moment may be determined for any center in Fig. 3. For example, it is PL at the support and $PL/2$ at the midpoint. In designing a beam the point of maximum moment must be determined for use in determining the size of beam which will support the desired loads.

It would be difficult to understate the importance of a thorough understanding of the principle of moments. In fact, it has been said that if the concept of moment were removed from engineering, it, as a science, would collapse. Torque, too, is moment, but is applied to actual rotation, as with shafting. Work is also expressed in foot-pounds so, as a

distinction, it is frequently proposed to express moment and torque in pound-feet. But long established custom, to say nothing of euphony, has set up what looks like an insurmountable barrier to its general adoption. And the question isn't of much importance except to the purist, since their connotations would prevent confusion of the terms.

The positions of the centroids of areas and the centers of gravity of parts or of finished machines or structures are determined by the method of moments. Since an area can be considered as a force concentrated at its centroid, an area for which the centroid is to be determined can be broken into a number of smaller areas the centroids of which are known, and the moments of the areas taken about each of a pair of convenient axes. The sum of the moments about each axis, divided by the total area, gives the distance from the centroid of the total area to the axis. In Fig. 4 the area of each smaller area is 4. Then $(4 \times 2\frac{1}{2} + 4 \times 4)/8 = 3\frac{1}{4}$; and $(4 \times 2\frac{1}{2} + 4 \times 5)/8 = 3\frac{3}{4}$. The intersection of these two moment arms of the area locates the centroid of the entire area. If the axes are taken between the ends of the object, then care must be taken to give the moments their proper sign; that is, right-hand, or clockwise rotation is given the plus (+) sign, and left-hand rotation the minus (—) sign. It is usually safest to use ends of the object as axes and thus avoid a confusion of signs. Openings, where it is convenient to consider them, are given a minus sign.

Some find it difficult to identify the resistance of a beam as a moment. Each "fiber" of a beam bears a portion of the total stress proportional to its distance from the neutral axis (axis normal to the force, through the centroid of section). If, on a section of a rectangular beam diagonals are drawn as in Fig. 5, each hatched triangle represents the total force acting on that side of the neutral axis. The area of a triangle equals the base times one-half the height, in this case $b\ h/4$, and its centroid is at one-third its height from the base. Since the entire tensile and compressive forces can be considered as concentrated at the centroids of the triangles, the arm of the resisting moment is then two-thirds the depth of the beam. Hence, the measure of the strength of the beam is the area of one triangle times the distance between the centroids of the two triangles. This value, $bh^2/6$ for a rectangular beam about a neutral axis, as in Fig. 5, is known as the section modulus, Z. Section moduli for other sections (squares, circles, etc.) can be found in handbooks under "Elements of Sections." Multiplying Z by the allowable fiber stress f gives the resisting moment of the beam and also the bending moment, or $M_r = M_b = fZ$.

In Fig. 6 are shown the bending moment formulas for two simple beams, one with a concentrated and the other with a uniform load. The bending moment formulas for other beams with the simpler kinds of loadings may be found in most of the handbooks of engineering (such as Kent and Marks). The handbooks of the manufacturers of structural steel shapes (such as "Carnegie Pocket Companion") are especially valuable. But in the chemical, and other plants, some very peculiar loadings may be found. In Fig. 7 is a side elevation of one of a pair of steel girders that supported a bin serving two ball mills, a jack-shaft carrying the pulleys driving the mills, a pulley belted to the motor, and a runway. The layout as shown was adapted to existing foundation piers. The weight of bin and contents was 50 tons. The runway with its assumed dead and live load added 1,200 lb. Since the pulley driven by the motor was close to the end hanger which was as close to one of the girders as possible, one girder was assumed to carry a half of the jackshaft, the pulley driven by the motor and a pulley driving one of the mills, the total weight of which was 1,745 lb.

Each ball mill required about 50 hp. at full load, and a 100-hp. motor was provided for the two mills. The angle of the ball-mill drives was about 30 deg. with the floor; and the angle of the motor drive about 45 deg. The speed of the jackshaft was 200 r.p.m.

The ratio of tensions of the two strands of a well designed belt drive is about three; that is, the pull of the "tight" strand is about three times that of the "loose" strand. Therefore, the pull on the shaft is about twice the net, or effective, pull as derived

Fig. 1 — Tension and compression prisms showing unit stress

Fig. 2 — Effect of eccentric loading on compression prism

Fig. 3 — Comparison of moment and torque

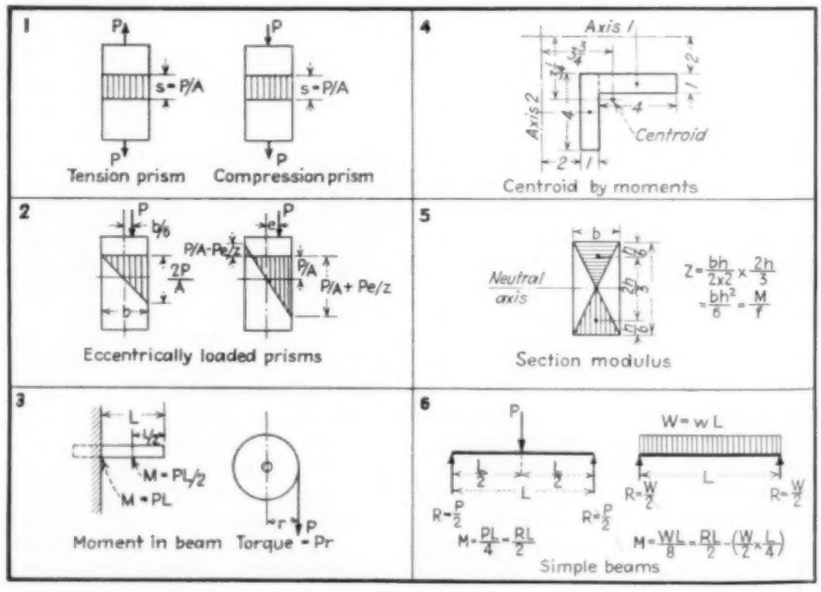
Fig. 4 — Determining centroid by method of moments

Fig. 5 — Derivation of section modulus for rectangle

Fig. 6 — Moment formulas for two simple beams

Nomenclature, Figs. 1–8

A = Area, sq. in. or sq. ft.
b = Width, in.
d = Diameter, in.
D = Diameter, ft.
e = Eccentricity of loading, in. or ft.
f = Extreme fiber stress, lb. per sq. in.
h = Height, in.
L = Length, in. or ft.
M = Moment, in.-lb. or ft.-lb.
P = Concentrated load or force, lb.
r = Radius, in. or ft.
R = Reaction, lb.
s = Unit stress, lb. per sq. in.
w = Unit load, lb. per ft.
W = Load or weight, lb. = wL.
Z = Section modulus, in.^{3}



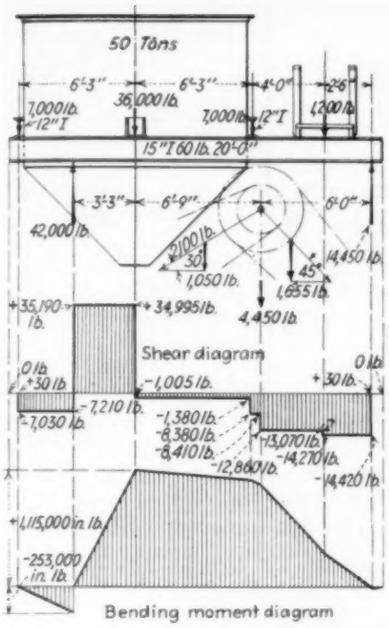


Fig. 7 — Design of beams supporting complicated load

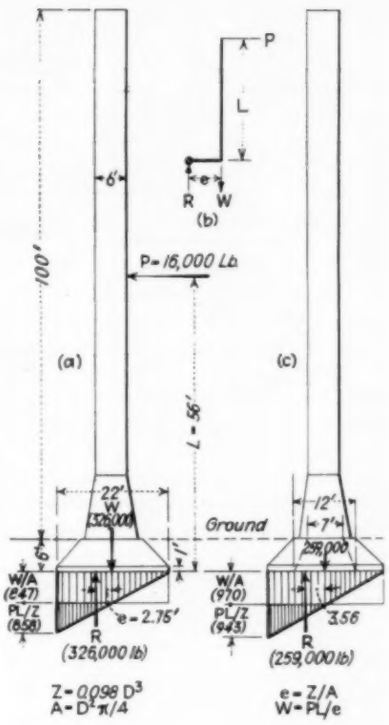


Fig. 8 — Design of foundation for self-supporting chimney

from the power transmitted by the drive.

The net belt pull = 33,000 × hp./π × Diam. × r.p.m. The ball-mill driving pulley was 30 in. in diameter, so the net belt pull was 50 × 33,000/200 × 2.5 π = 1,050 lb. The pull on the shaft was then 2 × 1,050 = 2,100 lb. The vertical component of this force was 2,100 sin 30 deg. = 2,100 × 0.5 = 1,050 lb. The motor driven pulley was 54 in. in diameter, and the net belt pull was 100 × 33,000/200 × 4.5 π = 1,170 lb. The pull on the shaft from this source was 2 × 1,170 = 2,340 lb., and its vertical component was 2,340 sin 45 deg. = 2,340 × 0.707 = 1,655 lb. Adding the vertical components of the belt pulls and the weight of the shaft and pulleys, there was a total force of 1,050 + 1,655 + 1,745 = 4,450 lb. acting on a vertical line passing through the shaft.

Two 12-in. I-beams 31.8 lb. were found in the plant and were used to carry the front and rear brackets of the bin. Their capacities were 14,000 lb. each under that kind of loading. One-half of this, or 7,000 lb., was carried to each girder. Assuming that the girder weighed 60 lb. per ft. and taking moments about the left-hand reaction, we had (36,000 × 3.25) + (7,000 × 9.5) + (4,450 × 10.0) + (1,200 × 13.5) + (20 × 60 × 6.5) = +252,000 ft. lb., minus 7,000 × 2.0) = +231,000 ft. lb. total. Dividing by the distance between supports we had 231,000/16 = 14,450 lb. for the right-hand reaction which, subtracted from the total load, gave 56,850 — 14,450 = 42,400 lb. for the left-hand reaction.

By moving to the right along the girder and adding the loads and reaction algebraically, the downward acting forces being negative and the upward acting reaction positive, we reached a point where the shear changes from positive to negative under the 36,000 lb. load imposed by the bin. This was the point of maximum bending moment. Taking moments about this point and giving the clockwise moments the plus sign and the counter-clockwise moments the minus sign we had + (42,400 × 3.25) — (7,000 × 6.25) — (6.25 × 60 × 6.25/2) = +92,880 ft.lb. net bending moment. With an allowable fiber stress of 16,000 lb. per sq.in., the required section modulus was $M/f = Z$ = 92,880 × 12/16,000 = 69.6 in.^{3} The section modulus of a 15-in. I-beam 60 lb. is 71.8 in.^{3} and this was used. The shear and moment at other points of the girder were found as in the foregoing and their values plotted as in the diagrams of Fig. 7.

The foundation of a self-supporting tower or chimney is correctly designed when there is zero pressure (i.e., impending lift) on the windward edge with the maximum wind pressure acting on the chimney. Greater than zero pressure indicates a larger or heavier foundation than necessary; and less than zero, or minus, pressure, would cause the chimney to tilt. There are many combinations of diameter and depth of foundation, and to arrive at the best would take several trial computations. Since the wind may come from any direction, a circle or a many-sided polygon (eight or more) is the best shape of foundation. The square ($Z = 0.118d^3$) is the poorest choice since its resistance about a diagonal axis is less than 84 per cent that of a circle ($Z = \pi d^3/32 = 0.0982d^3$) of the *same area* (diameter of equivalent circle = 1.128 × side of square).

An idea of the forces involved may be had from the bell-crank in Fig. 8 (*b*). P is the force of the wind assumed to be concentrated at the middle of the chimney; L is the length of the moment arm of P and the the distance from the point of application of P to the bottom of the foundation; W is the weight of the chimney and foundation; R is the soil reaction assumed to be concentrated at that point, and e the moment arm of W.

As an example we shall use a 6- x 100-ft. steel chimney. The maximum wind pressure is 30 lb. per sq.ft. on a flat surface, which reduces to 20 lb. per sq.ft. on the projected area of a cylindrical surface. Some building codes require a factor of safety of one and one-third for structures subject to overturning moments, so for the present example the wind pressure P is 6 × 100 × 20 × 4/3 = 16,000 lb. total, and the wind moment M is 16,000 × 56 = 896,000 ft.lb. A foundation 22 ft. dia., will have a value of $e = Z/A$ of $(\pi d^3/32)/(\pi d^2/4) = d/8 = 22/8 = 2.75$ ft. The required weight is then M/e = 896,000/2.75 = 326,000 lb. Subtracting the weight of the chimney, or 20,000 lb., we have 306,000 lb. for the weight of the foundation and the superimposed earth bounded by the dotted lines. Assuming a depth of 6 ft., and the form of Fig. 8 (*a*), the weight of the foundation is 239,000 lb., and the earth 63,000 lb., a total of 302,000 lb., which is close enough considering that the lateral resistance of the earth is disregarded. The maximum pressure on the subfoundation due the dead load is W/A = 322,000/380 = 847 lb. per sq.ft., and

due to the wind load $M/Z = 896{,}000/(\pi 22^2/32) = 858$ lb. per sq. ft., a total of 1,705 lb. per sq.ft.

In Fig. 8 (*c*) the foundation has been "cored" by the removal of a frustum of a cone whose upper and lower surfaces are 7 ft. and 12 ft. diameter, respectively. There is a worthwhile saving of 16 yd. of concrete. The area A is 267 sq.ft.; Z is 950 ft.^{3}, and e, or $Z/A = 3.56$ ft. The required total weight, chimney, foundation and superimposed earth, is $16{,}000 \times 56/3.56 = 252{,}000$ lb. The actual total weight in this case is 259,000 lb. The maximum pressure due to the dead load is now $259{,}000/267 = 970$ lb. per sq.ft., and due to the wind load is $16{,}000 \times 56/950 = 943$ lb. per sq.ft., a total of 1,913 lb. per sq.ft. Foundations supporting structures subjected to lateral forces can be cored and a saving effected for the same reason that makes hollow beams and columns economical.

Pressure Vessel Elements

Pressure vessels are familiar, not to say ubiquitous, details of the chemical plant. Their forms may be circular or rectangular, with the former predominating because of its ideal form for resisting bursting and collapsing pressure. Their heads or covers may be flat, dished, hemispherical or conical. Design of a thin shell is a simple matter, the force (hoop tension) tending to burst the plate in a unit length being $Pd/2$ in which P is the pressure in pounds per sq.in. and d the diameter in inches. Then $s = Pd/2t$ and $t = Pd/2sE + c$, where s is the unit stress in pounds per sq.in. (also the allowable stress); E is the joint efficiency; c is the allowance for corrosion, inches; and t is shell thickness, in inches. The design of the head is somewhat more difficult, and has received much attention from codes in recent years.

The API-ASME Code for unfired pressure vessels recommends the formula $t_1 = d\sqrt{CP/S}$ for flat bolted heads or covers, in which t_1 is the thickness, d the diameters shown in Fig. 9 *a* and *b*, C a constant depending on the method of attachment, P the allowable working pressure, and s the working stress.

In Fig. 9 *a* and *b* are two bolted heads, one with a "full face" gasket and the other with a "ring" gasket. The value of C for the former is 0.162 and for the latter is $0.30 + (1.4Wh_G/Hd)$ in which W is the total bolt load, h_G the radial distance from the bolt circle to the median line of the gasket, H the total end force on the *area bounded by the outside diameter of the gasket*, and d the diameter of the median line of the gasket, or contact surface. In the figures the dimensions given (in parentheses) are intended to make the two heads comparable and to show the influence of gasket width on thickness.

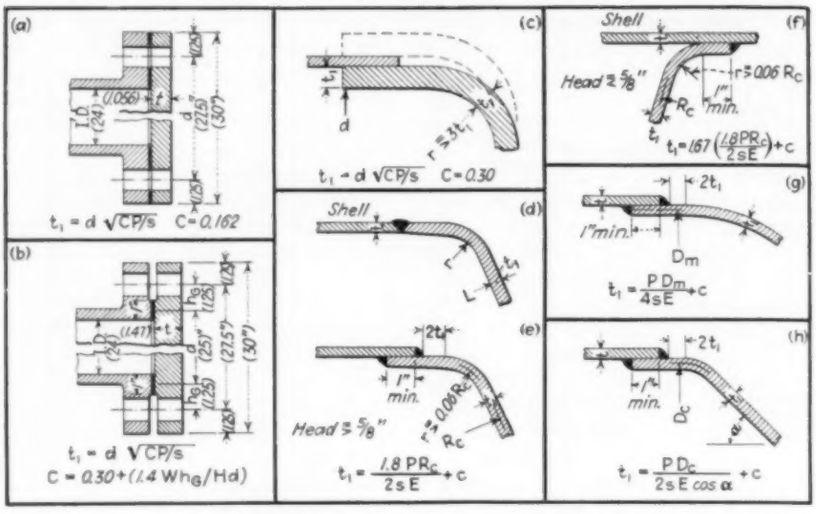


Fig. 9 — Formulas for heads specified in 1938 API-ASME Code

(a) and (b) Flat bolted heads
(c) Flat head for riveted, welded or brazed pressure vessel
(d), (e) and (f) Dished heads
(g) Hemi-spherical head
(h) Conical head

c = Allowance for corrosion, in.
C = Constant, values given in formulas
d = Diameter shown, in.
D_c = Mean diameter of cone at point under consideration, in.
D_m = Mean diameter of head before allowance for corrosion, in.
E = Efficiency of any head joint
h_G = Radial distance from bolt circle to center of contact surface, in.
H = Hydrostatic end force on area bounded by outside circumference of contact surface
L = Inside radius of crown, in.
P = Working pressure, lb. per sq. in.
r = Knuckle radius of heads, see drawings, in.
R_c = Radius to median line of crown, in.
s = Allowable working stress, lb. per sq. in.
t = Shell thickness, in.,
t_1 = Head thickness, in., see formulas
α = Half angle of cone at apex

For the head (*a*) the thickness t_1 for a working pressure of 100 lb. per sq.in., and $s = 11{,}000$ lb. per sq.in., is $27.5\ (0.162 \times 100/11.000)^{1/2} = 1.056$ in. For head (*b*) the term W in the formula for constant C is the total load on the bolts, or the area of the bolts at the roots of the threads times the allowable stress. W is also the total hydrostatic end pressure, i.e., the working pressure times the area over which it is assumed to act, plus the added pressure on the gasket, or contact surface, to insure tightness. The end area to be used is that corresponding to diameter d. The additional pressure on the contact area is left to the judgment of the designer, but for the present case is assumed to be the working pressure P times the area of the contact surface. The load W is then $(100 \times 26^2\ \pi/4) + 100 \times 25\ \pi \times 1 = 53{,}100 + 7{,}854 = 60{,}954$ lb. The hydrostatic end force H is $100 \times 26^2\ \pi/4 = 53{,}100$ lb., h_G is 1.25 in., and d is 25 in. The constant C is then $0.30 + (1.4 \times 60{,}954 \times 1.25/53{,}100 \times 25) = 0.3802$, and the thickness $t_1 = 25\ (0.3802 \times 100/11{,}000)^{1/2} = 1.47$ in.

The pressure on the gasket, or contact area, required to insure tightness, which is in addition to the hydrostatic end pressure H, is sometimes called "final gasket compression" and "residual gasket compression." Its magnitude is one uncertainty in the design of removable covers of pressure vessels. Another uncertainty is the actual area under pressure which, in the code, is assumed to be bounded by the outer circumference of the contact area.

In the formula for C in the last example, W was the sum of the hydrostatic end pressure and the working pressure acting on the contact area, the latter being H_G or the "residual gasket compression." If the residual gasket compression were increased several times, it would have small effect on the thickness of the cover. For example assume this factor to be increased four times, and the term on the right of the plus sign in the equation for W to be increased to 31,420 lb., then W is 84,520; C is $0.30 + (1.4 \times 84{,}520 \times 1.25/53{,}100 \times 25)$

$= 0.411$, and $t_1 = 25\ (0.411 \times 100/11{,}000)^{1/2} = 1.53$ in.

There is room for reasonable disagreement with the code in the matter of the actual area under fluid pressure and the diameter of the circle on which the resultant clamping pressure acts. But building and other codes are primarily concerned with safety, in the absence of which all other factors sink into insignificance. The difference between certainty and doubt may be a few cents' worth of material but a vast gulf for peace of mind.

The amount of residual gasket compression necessary to insure a tight joint depends on the condition of the contact surfaces and the method of tightening bolts. If the surfaces are smooth and true, and the bolts are tightened so as to avoid bending of the cover, either locally or on a diameter, the pressure required is small, as can be proved by considering the "pop" safety-valve.

The pop valve can be held to its seat by a pressure of only 1 lb. above the relieving, or popping pressure. The ratio of contact area of the valve to the area of its port or throat varies with the different makes but can be assumed as one-fifth. Then if 1 lb. over the working pressure suffices to hold the valve tight, then the contact, or residual pressure, is 5 lb. per sq.in. It would seem then that if the residual pressure were assumed as the working pressure times the contact area, it would be sufficient for all but abnormal cases.

The code value for C in the formula for the kind of head shown in Fig. 9c is 0.30, and the minimum inside radius of the head knuckle is $3t_1$. There is little justification for this kind of head, however, except for small sizes and low pressures, and, of course, when properly stayed. For a 24-in. diameter shell, and 100 lb. working pressure, the thickness t_1 is $(24—2t_1)\ (0.30 \times 100/11{,}000)^{1/2} = 1.13$ in.

Dished, hemispherical and conical heads all induce radial shear and bending moment for a short distance at the ends of the shell and head; which makes the head attachment of Fig. 9(e) superior to that of (d). The head of (d) was formerly designed under the ASME Code by the formula $t_1 = 8.33 \times P \times L/2 \times TS$ in which P was the working pressure, L the radius of the crown, and TS the ultimate strength of the material. The knuckle radius was $3t_1$, or $0.06L$, whichever was the smaller. The latest edition of the API-ASME Code approves this butt-welded head for thicknesses less than 2 in., when there is provided a "cylindrical flange or skirt, which shall extend beyond the point of tangency of the head and the element of the flange, or shell, a distance of not less than the thickness of the head plate." This clause would be clearer if accompanied by an illustration.

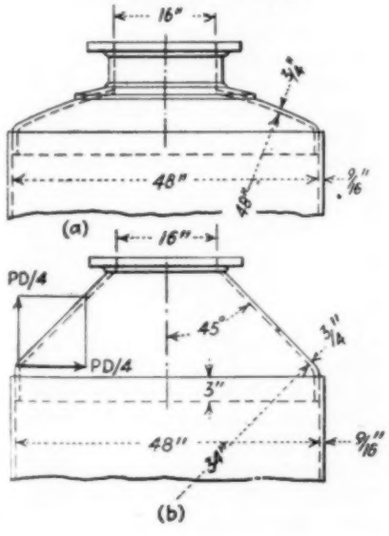
The head of Fig. 9(e), with its flange entering the shell, is more easily assembled than that of (d) and for that reason alone would seem to be preferable. The thickness of the convex head (f) is 1.67 times that of (e) for the same diameter and pressure. The hemispherical head of Fig. 9(g), though thinner than other heads for the same pressure and diameter, is somewhat costly, and is used principally for its appearance.

The conical head of Fig. (9h) has certain advantages over dished heads, which will be discussed presently. The maximum stress in the cone, both tangential and meridional, is at its base. Inserting the flange into the shell provides reinforcement against radial shear and its resultant moment.

In a job of ten years ago, the upper head of a 48-in. vapor heat exchanger was to be provided with an 18-in. manhole. The preliminary design was a common dished-and-flanged boiler head with the nipple and reinforcing pad welded to the head as shown in Fig. 10(a). This arrangement left little to be seen of the head and, as a bit more than the usual room for the workman while cleaning would not be amiss, a conical head was proposed. The head of Fig. 10(b) was installed. The working pressure was 200 lb. per sq.in., and with a joint efficiency of 80 per cent, and a stress of 11,000 lb. per sq.in., the required thickness of shell was $t_s = PD/2sE = 48 \times 200/2 \times 11{,}000 \times 0.80 = 0.545$ in. or $\frac{9}{16}$ in. The maximum stress in the cone was at its base, and was tangential; its magnitude being the working pressure P multiplied by the normal radius R_1. The angle of the cone with the axis was 45 deg., the normal radius was $24 \times 1.414 = 34$ in., and the required thickness of plate was $t_c = PR_1/sE = 34 \times 200/11{,}000 \times 0.80 = 0.77$ in. or $\frac{3}{4}$ in., agreeing with the present code.

The axial force at the junction of the cone and shell was calculated as $P(\pi D^2/4 \div \pi D) = 200 \times 48/4 = 2{,}400$ lb. per lineal inch of circumference of the shell. Since the angle of the cone was 45 deg. with the axis, the radial force due to the tendency of the pressure to blow out the head was of this same amount. These forces were the axial and radial components of the meridional force (along an element of the cone) and from an investigation of the force vectors involved it was evident that the radial force was inward, causing compression in the flange of the cone. It was assumed that this collapsing force was borne solely by the flange and an equal length of the shell, which together were considered as a ring of total thickness of $1\frac{9}{16}$ in. Opposed to the collapsing force was the outward-acting internal pressure within the cylinder. To determine the net compression in the ring, its height was taken as 3 in., on 1 circumferential in. of which an outward pressure of $3 \times 200 = 600$ lb. acted. Consequently, the difference between the inward acting compressive force and the outward acting internal pressure was $2{,}400 — 600 = 1{,}800$ lb. acting inward on 1 circumferential in. of ring 3 in. high. Comparable to the stressing of a cylinder under external pressure, the net compressive force in the ring was $PR = 1{,}800 \times 24 = 43{,}200$ lb. on the cross section of the ring. With an allowable stress of 11,000 lb. per sq.in., a joint efficiency of 0.90 (joints in cone and shell were staggered), and a ring thickness of 1.3125 in., the required ring width was $43{,}200/(11{,}000 \times 0.90 \times 1.3125) = 3.225$ in. Therefore, considering the restraint of the rest of the shell, a 3-in. flange was satisfactory. This head would have complied with present code requirements.

Fig. 10—Dished and cone heads for vapor heat exchanger



Effect of Codes on Design

BY HARLAN HOW, technical director of Struthers Wells-Titusville Corp., Titusville, Pa. A wartime chief engineer of the Cruiser New Orleans, Mr. How returned to peacetime pursuits in association with several leading process equipment fabricating companies where he served in both engineering and executive capacities.

DESIGN FOR OPERATION

A CONSIDERABLE PROPORTION of all recently manufactured pressure vessels have been designed and fabricated in accordance with the rules issued by some code authority. Fortunately, this is a desirable state of affairs and it has resulted in the gradual evolution of equipment construction from a perhaps questionable practice to one of certain safety and utility.

Before the actual design of a new pressure vessel is undertaken, the appropriate code under which this particular class of vessel is covered, or under whose jurisdiction the vessel will be placed and maintained in service, is selected. Rigid insurance requirements may render the installation of any but a code vessel impossible. There are a number of codes, including the ASME, the API-ASME, Federal, and various state codes covering the several widely distinct classes of pressure vessels. Among the types for which complete constructional methods or details can be found are heating and power boilers, miniature boilers, and unfired pressure vessels, including those containers to be used for storing petroleum liquids and gases. These codes have many points of common agreement, and several are verbatim copies of the corresponding ASME code.

Before the advent and general application of code construction, the general specifications for classes of carbon-steel plate, as given by the American Association of Steel Manufacturers, included extra-soft, firebox, and flange quality steel. At the present time the ASTM designation is a widely recognized standard and these specifications both physical and chemical in nature, have been adopted with few exceptions by all authorities. As a rule, each individual code specifies the particular grade or the corresponding ASTM designation of the steel to be used for a definite application. Specifications cover carbon-steel plate, forgings, pipe, and castings—also, plain and alloy-steel bolting material. Appropriate specifications are also available for corrosion-resistant metals and alloys. The clad type alloys, such as stainless or nickel-clad, must have a sufficient quantity of the base metal to fulfill all requirements for the minimum shell thickness.

Since the maximum allowable working stress is ordinarily based upon the minimum value of the specified range of tensile strength of the steel, it is apparent that the design factor of safety to be applied becomes the decisive and important item. In this particular, considerable variation will be encountered in different codes and especially in the type of riveted or welded joint. The maximum allowable factor of safety varies from 4 to 6 for riveted construction and from 4 to 5 for the fusion welded type of fabrication. Additional factor allowances are sometimes stipulated for various grades of steel, abnormal metal temperatures, types of joints, welding technic and supervision, thermal stress relief, and the radiographic examination. Non-ferrous materials, such as brass and copper tubing, are usually given a definite maximum allowable working stress which eliminates the factor of safety from the calculations.

The well known method of determining the minimum shell thickness, based on the maximum allowable working stress is permitted with but few exceptions. The significant factors are the efficiency of the longitudinal joint, the diameter of the weakest course, and the desired maximum working pressure. Considerable variation in the interpretation of the diameter is met with because inside, outside, and sometimes the mean diameter are being used, while relatively thick-walled vessels may be calculated by an entirely different formula. Restrictions are placed on the minimum value of shell thickness, depending upon whether the joints are of the riveted or welded type, and upon the maximum shell thickness for various classes of welded work.

Calculations for vacuum vessels and those subjected to high external collapsing pressure require a somewhat different treatment. A classic method, still applicable to the design of dished heads having pressure on their convex surface, was the allowance of a 60 per cent external pressure for a like shell designed for a certain internal pressure. Formulas for determining the collapsing pressure allotted the thickness exponents variance from 2 to 3, and exponents for the diameter were given values anywhere from 1.75 to 3. Such haphazard and rule of thumb methods were practiced with the result that some manufacturers built vessels having almost twice the wall thickness of a competitor's product.

In 1910 it was stated that experiments conducted on lap-welded steel tubes 3 in. to 10 in. in diameter brought out the fact that the length of the tube, provided it is not less than 6 times the diameter, has practically no effect upon the collapsing pressure. Flange seams for furnace flues in which the transverse edges of the plates are flanged outwards and riveted together with a ring between them, were first introduced by Mr.

Daniel Adamson in 1851. The Adamson ring type furnaces are constructed with ring spacings of 18 to 24 in. Thus, while the value and importance of reinforcing rings for externally-loaded pressure vessels was generally realized, definite, and quantitative data was usually lacking.

Code methods and procedures for the design of vessels for external pressure are largely graphical. Reinforcing rings, often of the T-bar type, are given full credit and through their logical employment a worthwhile saving in expensive material for a solid corrosion-resistant vessel is made possible. On the opposite extreme, the employment of a much smaller number of reinforcing rings for a plain carbon-steel vessel will be likely to strike the optimum balance between labor and material costs. In connection with vessels subject to collapsing pressure, the importance of true circle rolling of shell plates and perfectly formed heads cannot be over-emphasized. Although the effect of internal pressure is to perfect an originally imperfect spherical form, quite the opposite is true of an externally-loaded shell or head. In the latter instance, the tendency is to aggravate any deviation from a truly spherical surface. Code requirements dictate the maximum permissible difference between the maximum and the minimum diameters.

A wide choice in the selection of a suitable head for the pressure vessel is at the option of the designing engineer. Suitable types of approved closures are the ellipsoidal, dished, hemi-spherical, conical, and flat cover types. The minimum plate thickness for any of the foregoing is essentially a function of the tensile strength of the plate, the dish radius, the efficiency of any head joint exclusive of the joint to the shell, and, naturally, the desired maximum working pressure. In addition to these factors, calculation of flat cover plates also involves a constant, the value of which is dependent upon the method of attachment of the cover plate to the shell. Unstayed dished heads with the pressure on the convex side are allowed a maximum working pressure of 60 to 70 per cent of that for similar heads having the positive pressure on the concave side. Another code specifies that the head thickness shall be increased by dividing by 0.6 for an equal convex pressure rating. The proportions of dish and corner radius, flanges, as well as possible additional thickness for reinforcement of heads containing manholes, are provided for in various ways. Points of agreement covering dished head design are two: (1) that the dish radius be not greater than the diameter of the attached shell, and (2) that no head, with the possible exception of the hemispherical form, shall be of a lesser thickness than that required for a seamless shell of equal pressure rating.

Providing full consideration of temperature rating be made, steel bolted flange connections of the American Standard Series are ordinarily used. Otherwise, the proportion for approved type bolted flanged connections are determined by a mathematical method involving a number of factors, including total bolt load, cross-sectional root area of the bolts, maximum allowable unit working stress for the bolting material, total hydrostatic end force, and the maximum allowable working pressure. Additional factors, applying to bolted flange connections are: the area bounded by the outside diameter of the contact surface, total gasket or contact load, contact-pressure ratio and the area of contact surface. For the majority of applications standard commercial carbon-steel bolting material is permissible, particularly for the lower temperatures and pressures, while alloy-steel bolting material of specification quality is required for vessels which will be subject to excessively high temperature or pressure. A number of alternate methods of attachment of these connections to the shell plate are permitted.

Codes Affecting Equipment Design

Codes	Types of Vessels Covered
ASME	Power boilers. Locomotive boilers Low-pressure heating boilers Miniature boilers Unfired pressure vessels
API.-ASME. (Petroleum refining and production)	Unfired pressure vessels
Interstate Commerce Commission (Interstate railroad and truck lines)	Locomotive boilers Car tanks Truck tanks
U. S. Bureau of Marine Inspection and Navigation (Marine work)	Boilers Unfired pressure vessels
American Bureau of Shipping (Marine work)	Boilers Unfired pressure vessels
Lloyds (Marine work)	Boilers Unfired pressure vessels

Rules governing the size, type thread engagement and placement of nozzles and the requirements for reinforcement are quite explicit in any given code. Where such reinforcement is required, careful and approved design will fully compensate for the material removed by the opening. Inspection openings, handholes, and manholes are commonly required and adequate provision for these and their possible reinforcement must be made while the vessel is in the preliminary stages of design.

Although riveted construction is still practiced in certain cases, for obvious reasons fusion welding has largely supplanted this older method of joining the longitudinal and girth seams of pressure vessels. The commonly used welded joints, including the single and double-welded butt or lap joint, with or without plug or intermittent welds, are permissible under definite restrictions as to plate thickness and service for which the vessel is intended. The code welding procedures, tests, inspection and supervision have all served to unify and create the utmost confidence in this distinctly superior method of fabrication. The class of welding to be followed is determined by the service requirements and the plate thickness. For the highest class of welded work, producing a vessel which may be used for practically any purpose, all longitudinal and circumferential welded joints require radiographic examination with a technique which will discover any significant defects. Comparison with standard plates divulges imperfections which must be remedied by cutting and rewelding before such vessel will be approved for a designated service. Finally, for such vessels, a complete furnace stress relief will be given to release any distortion and locked-up stresses which may have been caused by the welding operation. The proper heat treatment for the stainless vessel is quite necessary for the highest corrosion resistant properties and maximum useful life.

Occasionally an unusual design problem will arise for which the actual strength of the part may not be reliably calculated. A proof hydrostatic test, in which the questionable portions of the vessel are covered with a brittle paint, provides a method of checking and approving such a design. In all cases, approved pressure relieving devices of adequate venting capacity, must be provided to insure safe and continued operation of the installed pressure vessel.

WHITHER DESIGN?

Fig. 1. Complete petroleum refining unit including fractionating column

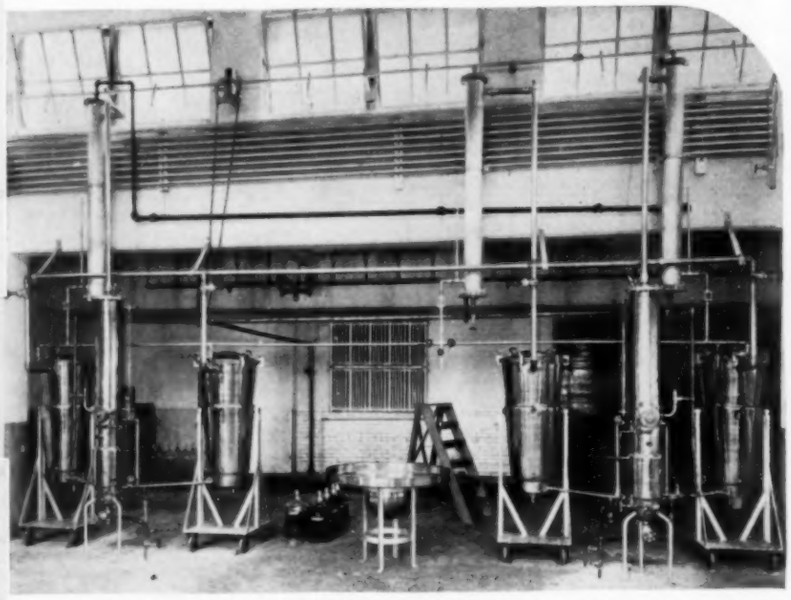


Fig. 2. An 18-8 stainless steel with 2 to 4 per cent molybdenum was selected for construction of these pieces of equipment used for extraction of drugs

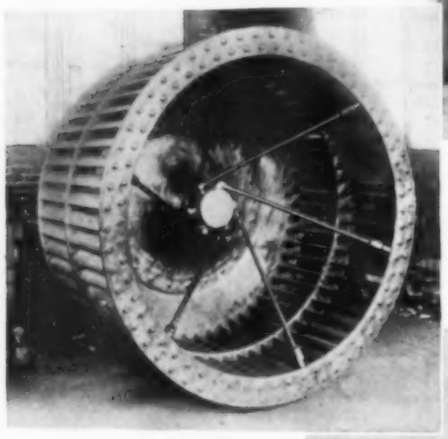


Fig. 3. 90-in. Multivane fan wheel completely homogeneously lead lined

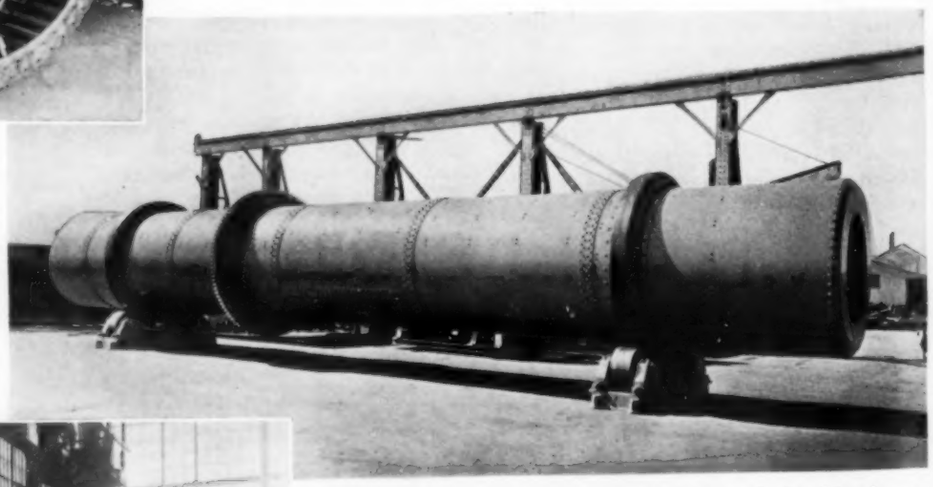


Fig. 4. An interesting feature of design of this bicarbonate of soda dryer is the cast tooth construction of the large gear which eliminated machining of gear teeth

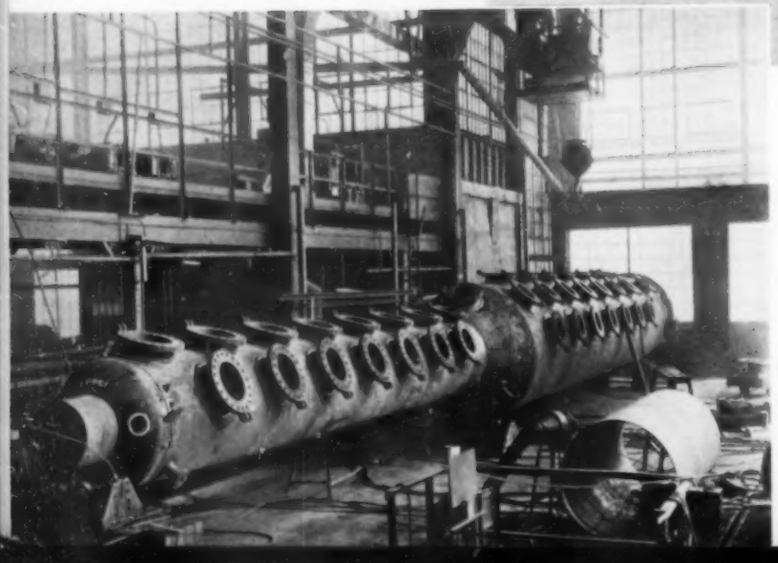


Fig. 5. Stabilizer tower. Fusion welded to A.P.I.-A.S.M.E. code for unfired pressure vessels. Stress relieved and seams X-rayed. Design pressure 250 lb. per sq. in. and tested at 472.5 lb. per sq. in.

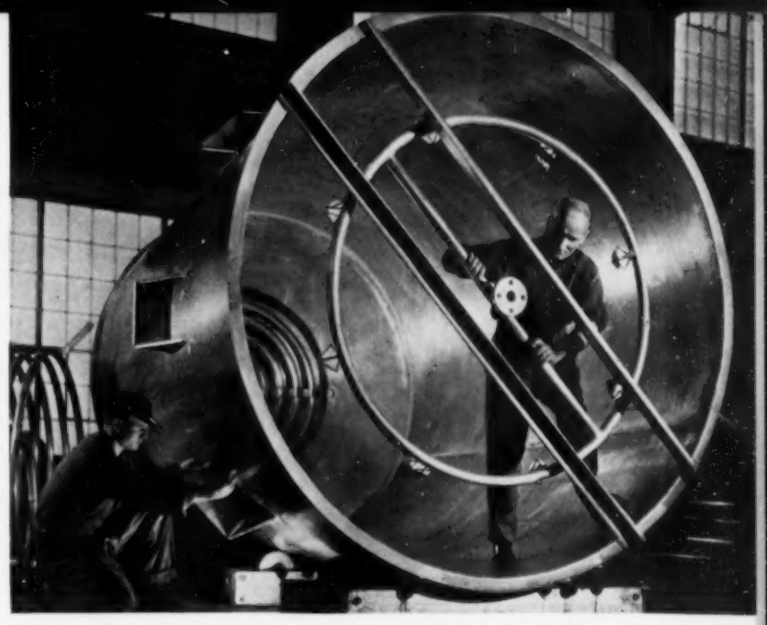


Fig. 6. Aluminum tank used for processing linseed and other oils. It is equipped with a helical heating coil and a special type of inlet distribution pipe. The pipe is provided with baffles which cause liquids entering the tank to cascade

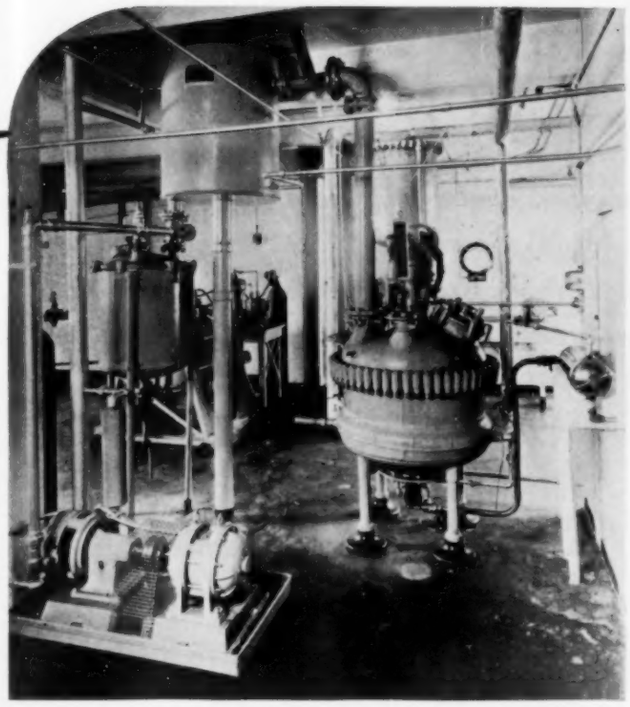


Fig. 7. Modern design distillation assembly, all glass-lined including jacketed still, condenser, receiver, tilting kettle, etc., in plant of Hynson, Westcott & Dunning, Baltimore

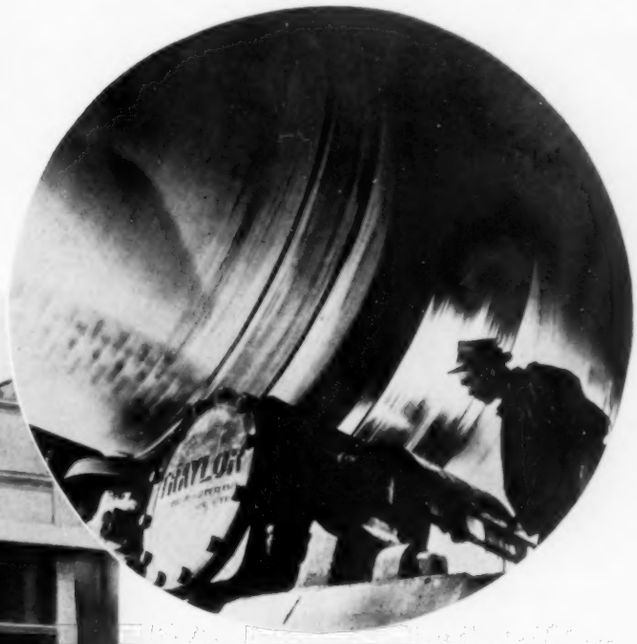


Fig. 8. Lime kiln and bearings in the recovery department of the Saltville, Va., plant of Mathieson Alkali Works

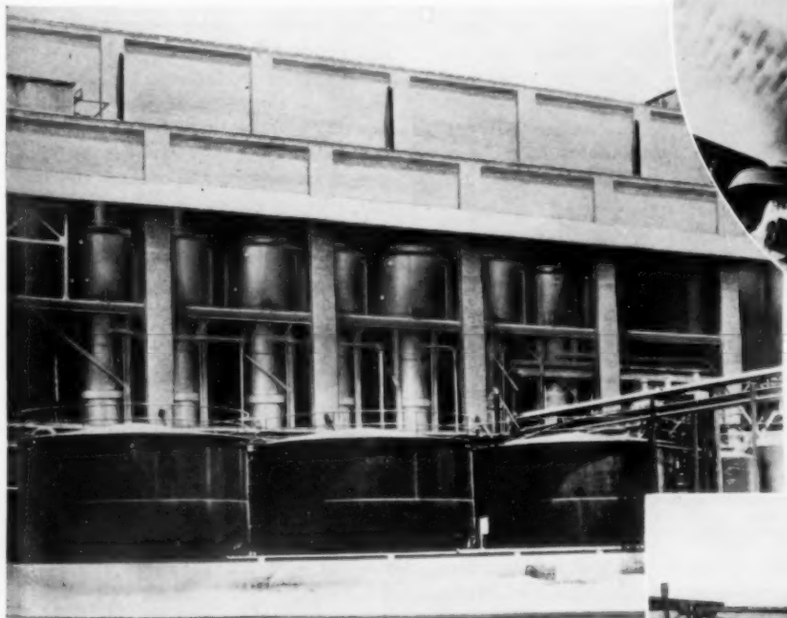


Fig. 9. Stream-lined multiple-body quintuple-effect long-tube-vertical evaporator for black liquor in a kraft pulp mill. Said to be the largest in the world

Fig. 10. Three hydroseparators above. Directly below are the same number of classifiers preparing high specification concrete sand at the Grande Coulee Dam, Mason City, Wash.

These illustrations were furnished through the courtesy of the companies mentioned below. (1) Leader Iron Works, Decatur, Ill.; (2) Brighton Copper Works, Cincinnati, Ohio; (3) Homogenous Equipment Co., Downingtown, Pa.; (4) Meehanite Research Institute, Pittsburgh, Pa.; (5) Henry Vogt Machine Co., Louisville, Ky.; (6) Aluminum Co. of America, Pittsburgh, Pa.; (7) Pfaudler Co., Rochester, N. Y.; (8) Mathieson Alkali Works, New York, N. Y.; (9) Swenson Evaporator Co., Harvey, Ill.; Dorr Co., New York, N. Y.

Storage and Reaction Vessels

BY CHARLES O. BROWN, consulting chemical engineer, New York, and specialist on high pressure industries and alkalis. At various times a technical executive of Solvay Process Co. and later of Nitrogen Corp., Lt. Col. Brown was also one of the organizers of Nitrogen Engineering Corp. He has been interested largely in plant design.

DESIGN FOR OPERATION

VESSELS for process industry use may be classified in several ways. A convenient method is to consider simple non-pressure tanks in which no special means is provided for heating, cooling or agitation; low-pressure reaction vessels; and pressure vessels. The dividing line between the second and third classifications is not definitely standardized, for what is high pressure in one industry may be considered low or moderate in another. Perhaps the best way to distinguish is on the basis of the methods used in design. When the required wall thickness becomes great enough to invalidate the simple stress formulas the lower boundary of the high pressure region may be considered to have been reached. (Vessels in the high-pressure class will be treated in a second article to appear in June.—Editor.)

Simple Tanks

In the case of simple non-pressure tanks intended primarily for storage, the design is usually determined more by economic and manufacturing considerations than by stress-strain calculations. Although such calculations should be made as a guide, they may be of secondary importance, especially with open tanks. Designing tanks of this type requires careful consideration to the details of fabrication, the economy and suitability of standard stock sheets, in addition to calculations to decide the proper thickness of material. Where a tank must fit a restricted space, this requirement obviously will fix the dimensions and many of the design details. More frequently, however, this restriction is lacking and design with the greatest economy for a suitable working capacity and overage (see Fig. 1 for capacity of dished ends), becomes the problem. The working temperature of the tank must be known and the requirements of the code under which the tank is to be built determined in this respect. In fact, a working knowledge of the code should be the first requisite.

After the capacity is known the dimensions of height and diameter are selected, the diameter of course conforming to standard sizes if dished ends, flanged saddles or other standard accessories are to be used. After the dimensions have been selected and checked for conformity with stock materials, the final calculations are again made to check the weight of material and harmonize the design with the code requirements. All vessels should be permanently marked to show the type and use to which the vessel may be put.

The selection of the diameter and height of vessels may be governed almost wholly by the width and length of convenient standard sheets, to the end that when formed a single sheet may, if possible, make the tank shell with one seam and without cutting the sheet. The tank is then finished by adding a bottom. A conservative overage capacity should be based upon the method of filling and emptying the tank, safeguarding the contents against agitation, and other causes of spattering and spilling. The determination of thickness of walls and bottom must take into account stiffness and rigidity based upon the physical properties of the materials used. Vessels intended only for storage in one location may be designed primarily on the stresses caused by the weight and hydrostatic head of the contents, but if a vessel is intended for transport, then the requirements for rigidity become of first importance, increasing the weight of materials and requiring special details of construction. There are important requirements in the codes for vessels used in transport.

Design formulas and data for all cases of simple non-pressure vessels are to be found in the standard handbooks.[1, 2] In simple tanks of steel, the design may be based upon an ultimate strength of 60,000 lb. per sq.in. in tension and compression; and 50,000 lb. per sq.in. in shear. If we let P = the uniform unit working pressure on the inside surface of vessel in lb. per sq.in.; l = the length of cylindrical shell in inches; d = the diameter in inches; s = the unit tension in the material, in lb. per sq. in.; and t = the thickness of the wall, in inches, then the internal force tending to rupture $= P\ l\ d$ and the circumferential stress resisting longitudinal rupture $= 2\ s\ t\ l$. Hence

$$s/P = d/2t \text{ or } t = Pd/2s \qquad (1)$$

The longitudinal stress (stress on a circumferential seam) is half the circumferential stress and is then given by $P\pi\ d^2/4 = s\ t\ \pi\ d$ and

$$s/P = d/4t \qquad (2)$$

When a simple tank is to be rectangular, with flat sides, it is often instructive and helpful to lay out the sides of the tank to scale as if it were unfolded from a single piece, and study the shape or pattern of the tank in a single horizontal plane. If the shape of this view is very irregular, it indicates excessive cutting of material, with perhaps consequent high waste or excessive welding. A little study may show that a simple change in dimensions will make a much cheaper tank, also having the required capacity.

In modern practice small non-pressure tanks are practically all welded. The writer believes that there are no conditions today which indicate the

economy or desirability of riveted construction for tanks, with the exception of very large tanks requiring field erection, which happen to be located in a fire zone where open flames are not permitted. In this one special case a riveted tank using cold hammered rivets is probably preferable.

The preparation of steel sheets and fittings for welding has been the subject of much careful design.[2] The object of preparation is to permit a weld which will have a strength equal to the parent metal, so placed that the rough weld surface will not be poorly located, and will not obstruct and interfere with important parts of the vessel such as gasket surfaces, or threaded fittings.[2]

The fact that a certain weight of metal is required in small non-pressure tanks, not from the standpoint of strength but from the standpoint of rigidity of construction, often penalizes the use of alloys of very high tensile strength unless thin sheets of the desired alloys are bonded to steel. For the construction of small vessels even this clad material may not result in an economy, since the cost of the low weight of the pure metal required may be no higher than that of the alloy-clad steel for the same tank. In tanks of larger volumetric capacity, however, alloy-clad steels show some saving in proportion as the tank increases in size, and in this field it is well to study the various design factors quite carefully in order to approach the allowable physical properties of the material and still obtain safe and conservative design.

Considerably more importance attaches to design calculations when a simple tank of the low-pressure type is closed with a cover. In addition to calculating the thickness of metal for walls and bottom, the designer must (1) make a study to determine if special treatment by bracing or press shaping is needed for rigidity and stiffness; (2) calculate the necessary gasket pressure; (3) calculate the type and weight of flange; (4) determine the size and number of bolts needed to resist the internal pressure and develop the desired gasket pressure; and (5) calculate the cover design requirements which, although similar to the bottom, must make provision for the special functions of a cover, such as the support of accessories.

After selecting the fiber stress permitted in the material of the side walls, the thickness of the material is fixed by the hoop-stress formula (1). If this calculation indicates what appears to be an excessive amount of metal in the side walls, this is reason enough to consider reducing the diameter of the tank to make a lighter material possible, obtaining the desired volume by increasing the length of the tank. Calculation of the weight of material for a dished or dome end of the tank is based on a variation of Equation (1) as shown in the API-ASME Code.[3] (See also Fig. 9 and text on page 304 of this issue.—Editor.)

In small steel tanks 2 to 4 ft. in diameter, it is not economy to use less than $\frac{3}{16}$ to $\frac{1}{4}$ in. metal, regardless of the design calculation. Ordinarily a simple cylindrical non-pressure tank will consist of two welded seams, one down the shell in a vertical position and a welded seam in the horizontal plane joining the side walls to the bottom. The detailed preparation of the metal for making these joints is well illustrated for certain cases in the practice sections of the various codes. For non-pressure tanks, especially those standing vertically, a flat bottom is satisfactory and has the advantage that such tanks are easily gaged and cleaned; but such tanks will not withstand much pressure when large in diameter. Covers for tanks of this type are ordinarily attached by welding a flange to the top of the tank, sufficient to contain a gasket surface and the necessary bolt holes. The shop details and method of dressing the plate to make an efficient and economical weld have been described by Sandstrom.[3]

Fig. 1—Capacity of dished heads

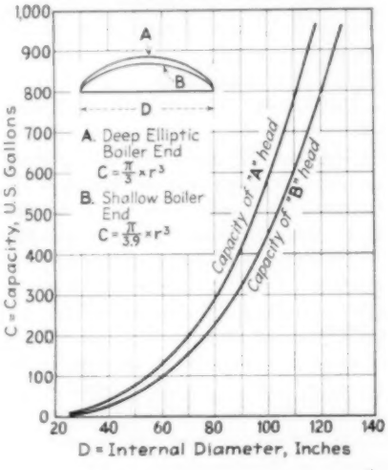
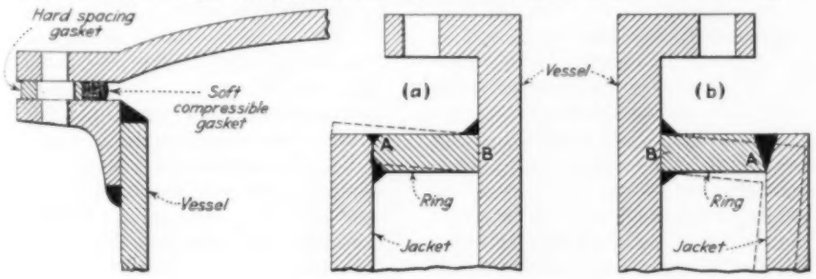


Fig. 2—Left—Special double gasketing avoids cover distortion

Fig. 3—Right—Rapid temperature changes distort jackets and may crack welds



Avoiding Flange Deformation

The simple flange gasket and flat cover bolted to the flange as a means of hermetically closing a cylindrical or rectangular tank has some disadvantages. The bolts are used to develop gasket pressures which must be of the order of twice the unit working pressure. This may deform the edge of the cover and, in some cases, the surface of the flange as well. This may be avoided by the use of two gaskets, one non-compressible and true to thickness, and the other a soft, compressible gasket with approximately 10 per cent excessive thickness, the two being assembled approximately as in Fig. 2. It is impossible to take off a cover which is deformed or bent, and replace it again so as to make the tank tight, but the double gasket as shown in Fig. 2 avoids trouble as it is impossible to deform the flange or cover when using the hard spacing gasket.

The final job in such tank design is to provide for the required outlets. If nothing especial is known about the requirements for such outlets, two are usually provided in the tank proper, so located that they are on the same side of the tank, unless definitely otherwise desired, and each outlet should be of a size permitting the tank to be filled or emptied in what the designer believes to be a reasonable time. In this regard, generalizing, a tank of any size should be emptied in perhaps a minimum of 15 minutes and a maximum of 1 hour, which fixes the size of outlets, usually calculated for gravity flow. The location of the top outlet on the shell of the tank should

preferably be at about the position of the liquid level when the tank is full to allowable capacity. The bottom outlet should be placed in the side wall of the tank, but so carefully located that emptying the tank and cleaning the tank may be conveniently accomplished. If special requirements in the operation of the tank are known, it may be necessary to put an outlet in the bottom plane, but in doing so, supporting the tank becomes more difficult and costly, and such outlets are never really accessible in vertical tanks.

Large size cylindrical tanks must provide for rigidity, so that the tank when empty will not assume an elliptical shape, and take on a different shape when full. Saddles are suitable for supporting such tanks, and should be not more than one diameter apart. Outlets on cylindrical tanks used in a horizontal position are usually all on the bottom, but access to the tank must be provided for, and this is accomplished by manholes either in the top of the horizontal shell exactly midway between the ends, or at the top of one end plate. Tanks mounted on railroad cars are also required to have a dome which has a false cover inside, through which are connected valves and safety reliefs.

Reaction Tanks

Reaction tanks intended for moderate pressures are designed using the principles given above, with modifications to provide for treatment of the material in the tank. While the tanks described above are primarily for storage, reaction tanks must usually provide also for safety under moderate pressure, agitation, heating and/or cooling. As mentioned above, it is often true that the necessity for rigidity requires a weight of material far in excess of that indicated by a stress analysis. The cover, for example, ordinarily carries the agitator support, drive shaft and pulleys, or motor.

The weight of material required in a bolted-on cover may be figured from the formula[4]

$$P = s\ (t - c)^2/Cd^2 \qquad (3)$$

where d = the diameter of the shortest span, inches (diameter of the bolt circle, or of the vessel in the case of a bottom welded-in); t = the minimum thickness required, inches; P = the maximum allowable working pressure, lb. per sq.in.; s = the maximum allowable fiber stress, lb. per sq.in. (for ordinary steel plate, 15,000 lb. per sq.in.); $C = 0.162$; and c = allowance for corrosion, in inches.

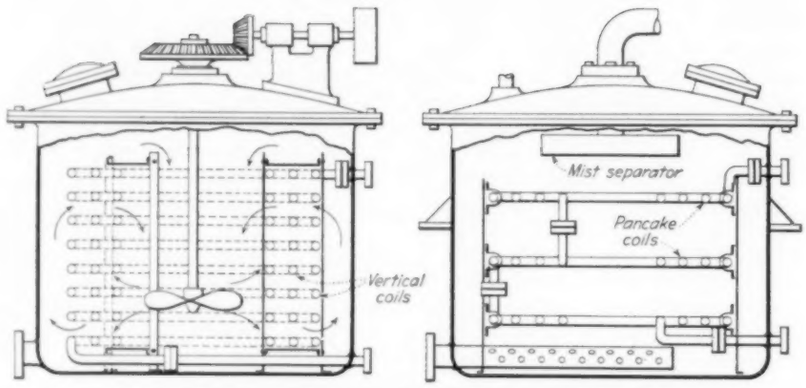


Fig. 5—Left—Concentric vertical coils in an agitated kettle
Fig. 6—Right—Pancake coils in a vessel without agitation

If no metal to allow for corrosion is provided, and the working pressure is 20 lb. per sq.in., the required thickness of plate for a 26-in. diam. cover is 0.382 in., but to carry the other loads referred to, 10 to 20 per cent increased thickness would be used, and possibly some bracing or fillets in addition.

Reaction tanks, if covered, must contain a sufficiently large manhole in the cover to permit a man to enter even relatively small tanks, for the purpose of facilitating inspection. This fitting usually stiffens the cover. When a tank designed without agitation as a simple tank is required for use with an agitator, it is modern practice to install a portable agitator made for the purpose by simply clamping the motor casing to the upper edge or flange in the tank. With a covered tank this possibility should be considered in the design of the manhole nozzle. The fittings on the various makes of portable agitators, it should be noted, have not been completely standardized.

There is also a trend in the design of agitated tanks to install the agitator as a unit on a large flanged opening on the side of the shell, ordinarily near the bottom of the tank. To this flanged opening is bolted a specially designed single-unit, motor-driven agitator with a propeller and shaft equipped with a stuffing box. This construction simplifies the design of the tank and eliminates rigid supporting cross members at the top or in the cover. As disadvantages are the facts that the shaft enters the contents in the tank and must be made tight with a stuffing box; while the saddle or flanged fitting which serves as a mount for the agitator is complicated because it must be mounted

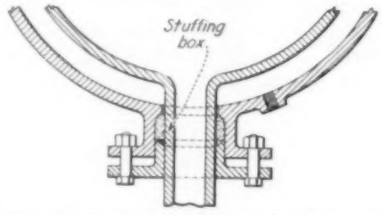


Fig. 4—Typical bottom outlet for cast iron kettle

tangentially. However, the top section and cover are simpler and lighter; the cover is relieved of vibration and disturbance to the gasket seat, and the size of the shaft required for a given size propeller is much less than for a long vertical shaft reaching from the top cover to the same propeller near the bottom of the tank.

Practically every reaction tank must be provided with either heating or cooling surfaces, or both. Space does not permit a full treatment of all the special vessels used in the chemical industry as reaction tanks and the complicated elements of design of nitrators, sulphonators and other special reaction tanks will not be detailed except as a general case. It is pointed out that when a tank must provide heating and/or cooling in addition to agitation, the problem becomes about three times as complicated as simple tank design. Generally heating and cooling surfaces are obtained by using the tank itself as one transfer surface and applying the heating and cooling medium by enclosing the tank proper in a jacket. This plan is very widely used but is not as simple as it appears. Serious troubles have arisen in use with some tanks of this class, which ordinarily would appear to be excellently designed. Long experience, however, convinces engineers that the duty on such a tank is extraordinarily severe,

and only by careful and intelligent analysis of the stresses and strains will such a tank be made safe.

A brief explanation of the development of one type of difficulty will indicate why the design of such a tank is not simple. Assume the case of a moderate sized tank used for heating an organic syrup to 120 deg. C. Immediately after the required temperature has been reached, it is essential that the contents of the tank be rapidly cooled. The tank is heated by steam admitted to an external jacket and the tank is cooled by admitting water to the same jacket. It is important to analyze carefully what happens in this case. Figs. 3*a* and 3*b* show a jacket design which is very simple and indeed quite practical and satisfactory from the manufacturer's point of view. There is a great deal to recommend this design in economy of materials and labor. There are two ways of fabricating the welded construction of this tank, both of which result in developing a simple jacket enclosing the vessel. Nevertheless, either method is open to the faults and dangers of this construction.

Heating of such a tank by the admission of steam in the jacket at 40 lb. per sq.in. pressure offers no difficulties. The jacket should be given a hydrostatic test once each six months to assure the safety of the jacket for this pressure, and the requirements for the use of this pressure are really not severe. However, trouble develops with the admission of cooling water. Referring to the sketch, it is apparent that at the end of the heating period point *B* is at 120 deg. C., and with cooling water flowing in, point *A* almost immediately reaches the temperature of the cooling water, 18-25 deg. C., at which time point *B* has dropped relatively little. We now have a condition of extreme stress in the ring closing the top of the jacket. Its outer diameter is at room temperature, and the compression stress in the outer edge of the ring is sufficient to distort the ring either upward as shown in sketch 3*a* or downward as shown in sketch 3*b*. This distortion of the ring occurs each heating and cooling cycle until failure of the weld takes place near *A*. This failure will probably occur when water is in the jacket, but a serious accident may follow when steam is admitted into the jacket, and full pressure reached. The design must be corrected by use of a more expensive ring closing the space between the jacket shell and the vessel, i.e., one which will flex without breaking the weld.

Another disadvantage of the outside jacket arises when a bottom outlet for the inner vessel is needed. In cast iron kettles the usual procedure is to supply a stuffing box to take care of differential expansion, as in Fig. 4. With welded construction the jacket is generally welded to the vessel bottom, rather than to the outlet pipe, since the temperature stresses are better taken in such a seam than by the smaller weld which would be used if the jacket were to be secured to the outlet pipe. An alternative scheme sometimes employed instead of a bottom outlet is to blow the contents through a discharge pipe through the cover.

It is evident, then, that outside jackets as a means of heating or cooling materials under reaction are not ideal. The surface usually is insufficient compared to the surface one would desire, but such jackets are widely used and will continue to be so used because half of the necessary surface, that of the tank itself, is byproduct surface, and not chargeable to the heating or cooling. Outside jackets also leave the interior of the tank free for agitation and for convenient handling of the contents. On the other hand, the attainable heat transfer rate through the wall of a jacketed vessel is somewhat low with steam in the jacket, and even lower when cooling. The rate of heat transfer is approximately proportional to the 0.8 power of the mass velocity and the shape factor of the jacket space will not permit of good velocities. Welded fins on the outer wall of the vessel proper will help to correct this condition by increasing the surface and the turbulence. It should be noted, however, that the temperature difference must not exceed an optimum value or actually *less heat will be transferred* owing to objectionable "skin effects" which develop.

If heating and cooling surfaces are developed by inside coils, which are desirable in some cases, the entire cost of the coils is chargeable to heating. The coils must be supported within the tank and arranged to permit agitation. The entire assembly results in making the cleaning of the tank a difficult operation. An advantage of inside coils is that a unit of surface in a coiled pipe can usually be arranged for much more efficient heat transfer than a unit of surface in a jacketed tank, with a high transfer coefficient outside and inside the coil. In the case of a jacketed tank, however, there is no reasonable way to agitate the heating or cooling medium in the jacket except by a high velocity due to the one pass of the fluid, and this of course requires that a large amount of fluid be used. Another complication although not serious, is introduced in developing methods to support a reaction tank with an outside jacket. There is, of course, more vibration in an agitated tank and considerable vibration during the boiling of liquids, so that tanks of this class must be adequately supported. Consideration of all the factors involved usually leads to four angle brackets welded to the jacket near the top, so that most of the space within the tank is below the supports, and the supports leave the bottom, the top of the jacket, the flange, gasket and the cover and agitator free and easily accessible. Agitation in jacketed tanks for obvious reasons is largely through the cover.

Design of Coils

The design of cooling or heating coils to be mounted in reaction tanks must provide for good circulation of the tank working load without excessive friction. The work of fabricating the coils is small when the pipe is rolled into a one-, two- or three-layer cylinder, as diagrammatically represented in Fig. 5. Agitation in the lower half of the tank is from the center out, and in the upper half of the tank from the outer walls to the center. The agitator may easily be withdrawn without disturbing the coils, which are carefully spaced and rest on the tank bottom. The circulation may be reversed by a propeller near the top of the coils, which forces the material at the top of the tank from the center outwardly.

Where gas absorption is taking place during heating or cooling, the coils are usually arranged in "pancake" form, as in Fig. 6. These coils rest upon the tank bottom, both types being connected so as to be fully self-draining. The fluid medium flows from top to bottom. In both types of tank, baffles may be fixed to the tank shell or to coil supports to direct circulation.

References

1. "Kent's Mechanical Engineers' Handbook," 11th ed., John Wiley & Sons, 1938, Vol. 3, Sect. 7, p. 44.
2. API-ASME Code, 1938.
3. C. O. Sandstrom, articles in *Chem. & Met.*, 1932 p. 668; 1933 pp. 91, 138; 1934 pp. 130, 360, 476; 1935 p. 94; 1938 p. 684.
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Plate Type Distillation Columns

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DESIGN FOR OPERATION

BUBBLE CAP PLATE COLUMNS are a type of process equipment usually tailor made to fit each specific service, and in the design of which the experience phase is an important asset. It is the purpose of the present article to review briefly the general considerations involved in the design of such equipment and to indicate approximate ranges of certain design variables found in current commercial practice.

Complete design of plate column equipment can be considered the result of the following procedures:

1. Design for fractionation or the degree of separation required.
2. Design for liquid-vapor contacting and adequate flow capacity for each of the countercurrent phases.
3. Design from the mechanical and fabrication standpoint.
4. Design of auxiliaries including heat exchange, condensing and reboil equipment, pumps and control instrumentation.

Because of space limitations, discussion will be confined to Items 1 and 2.

Design for fractionation involves the determination of reflux ratio and heat requirements as related to the number of fractionating steps or plates to effect the desired separation. This phase of design is well amplified and summarized by Robinson and Gilliland,[1] at least for mixtures of well defined chemical identities each present in appreciable concentration. For continuous mixtures, such as petroleum distillates, fractionation design is still largely on the empirical basis from the standpoint of trays and reflux required, although considerable published information is available on plate and reflux requirements[2].

[1,2] Refer to page 336 for bibliography.

A necessary corollary to fractionation design is the selection of operating pressure, which in turn defines the temperature levels throughout at which the tower will operate. Operating pressure is usually dictated by three considerations: (1) the temperature of cooling medium available for reflux condensation, (2) the closeness of approach to the critical region for the mixture handled and (3) avoidance of temperatures at which thermal decomposition may become rapid, which may require the use of vacuum.

In general, the lower the operating pressure and consequent temperature levels, the greater the volatility differences between components with lower reflux and reboil heat requirements. Illustrations of the effects of considerations (1) and (2) on column operating conditions lie in the separation of the lower boiling paraffines and olefines which has become of increasing commercial importance. Refrigerated reflux has been applied to these separations utilizing low temperature heat exchange and, in some instances, both direct refrigeration and energy recovery by expansion of overhead residue gases through expansion engines or turbines.

In general, design for fractionation may be considered to have passed from the stage where experience largely governs and this design phase is susceptible to detailed analysis by methods readily available. The results of fractionation calculations, however, can only be translated into the economics of first cost and operating expense when Step 2 has been investigated, involving determination of column diameter, column height and the detailed tray layouts required.

The classical treatment of plate tower design from the vapor and liquid capacity standpoint has been to treat tolerances in each of the major factors as more or less separate identities. Within recent years it has become generally recognized that such independent consideration may lead to very unsatisfactory results, and that an attempt must be made to evaluate each factor in relation to the others. This makes complete rationalization of this phase of column design extremely difficult and explains the fact that experience has continued to play a major role. While separate discussions of the several principal factors follow, an attempt will be made to point out, at least qualitatively, their general relationships.

Limiting Vapor Velocities

The safe vapor rate at which a column may be operated represents one of the primary factors in determining column size and economics. For many years it was considered that entrainment, or the mechanical carryover from plate to plate of relatively small liquid droplets, defined the limitation in vapor velocity for any given conditions. The results of many qualitative determinations of actual entrainment obtained with various liquid-vapor systems and small scale plate designs have been published within the past few years.[3, 4, 5, 6] These results, together with the mathematical analysis of the effect of entrainment *per se* on column performance[7, 8] lead to the following conclusions:

1. Entrainment may reach a high ratio in terms of weight of entrained liquid per unit weight of vapor before fractionating efficiency is impaired. (In cases where the elimination of minute traces of color or odor bodies is an accompany-

ing problem, entrainment *per se* may become of more effect.)

2. Before vapor rates are reached at which entrainment interferes with fractionating efficiency, other factors usually become controlling. These include basic changes in the mechanism of vapor liquid contact with vapor rate, froth or foam buildup on the tray, jetting or spouting action between caps and weir and downflow performance.

In view of the above complexity of the factors limiting safe operating vapor rates, any attempts at generalized correlation must be regarded as empirical expressions of commercial practice.

For many years designers have employed various variations of Equation (1) as a guide to vapor velocities.

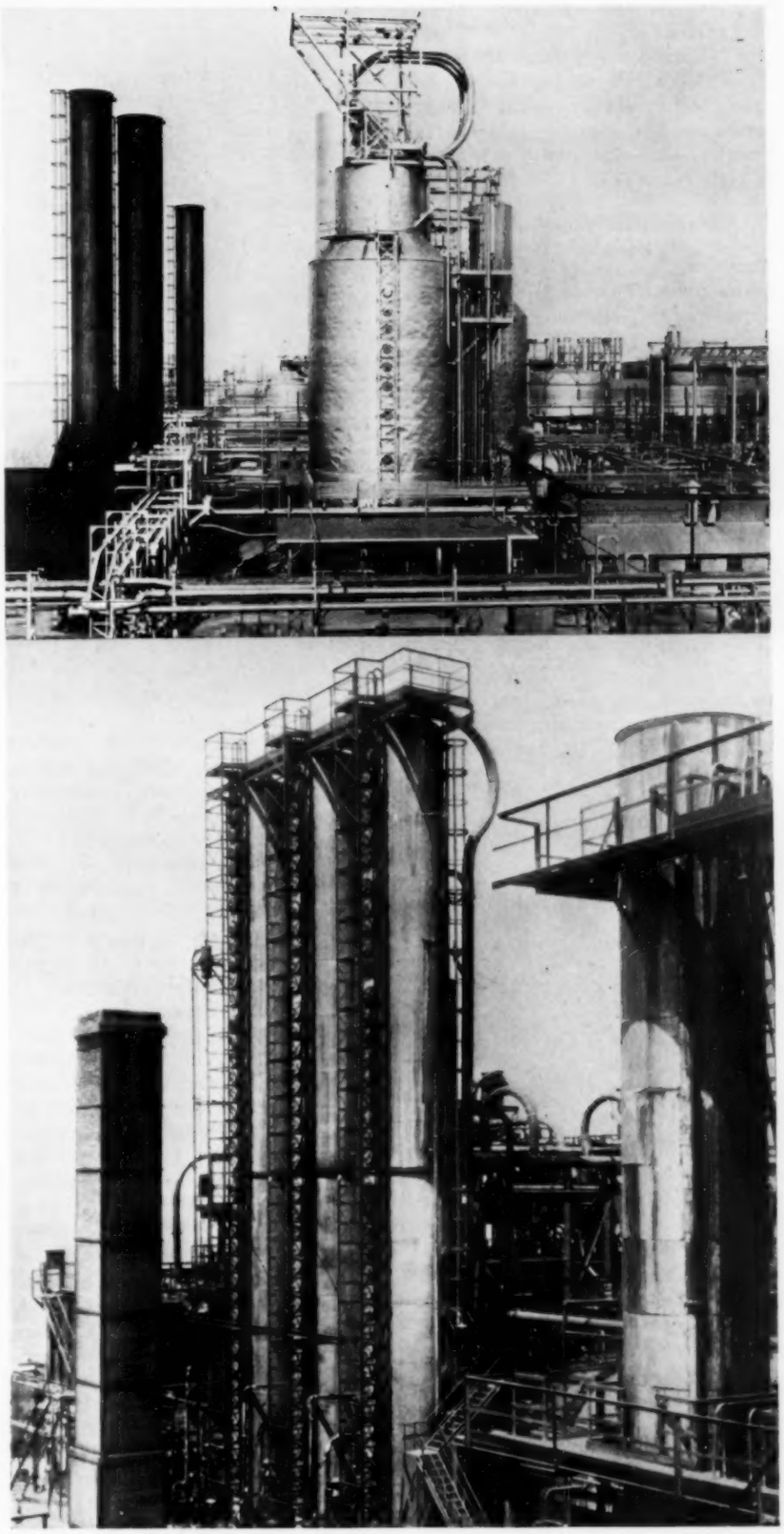
$$u = k\sqrt{\frac{d_1 - d_2}{d_2}} \qquad (1)$$

u = superficial vapor velocity (based on total column area), ft. per sec.
d_1 = density of liquid downflow under column conditions of temperature.
d_2 = density of vapor under column conditions. (With the increased commercial necessity for high pressure columns for certain purposes, the question of the vapor density to employ in Equation (1) has frequently arisen. Most designers of column equipment appear to prefer the use of the perfect gas law vapor density in their correlations, rather than an actual or calculated corrected value. This discussion, therefore, assumes the gas law vapor density with respect to d_2 and u).
K = Constant as defined by materials handled and tray design variables.

Equation (1) can be derived upon a theoretical basis by equating the fractional upward pull of vapor upon a suspended liquid droplet to the downward gravitational effect on this same particle. Hence the original significance attached to Equation (1) was as a means for the selection of a vapor rate which would substantially eliminate entrainment.

In view of the other factors recognized as of major importance, Equation (1) can now be regarded as an empirical expression useful in approximating workable vapor rates and diameters of fractionating towers, which, upon subsequent investigation of liquid flows, weir arrangements and cap spacings will not require too great modification.

The accompanying table represents an attempt to define semi-quantitatively values of K in Equation (1), based both upon the several published investigations cited and general commercial practice. (cf. Souders & Brown[9]). Referring to the table, it will be noted that tray spacing appears to lose appreciable significance in permitting higher vapor



Bubble cap towers are essential to many process industries; chief among them is petroleum refining. The tower shown above is a 32-ft. I.D. vacuum tower for reduced crude, and the lower view shows fractionating equipment

velocities for spacings above 30 in. Recognition of the effect of liquid seal (defined as height of liquid above the top of the cap slots based upon liquid density under flowing conditions but assuming absence of foam) is semi-quantitative only down to plate spacings of about 16 in.

Approximate Values of K in Equation (1)

Plate Spacing (in.)	Liquid Seal (0.5 in.)	Liquid Seal (1 in.)	Liquid Seal (2 in.)	Liquid Seal (3 in.)
6	0.02–0.04	.....	.....	.....
12	0.09–0.11	0.07–0.09	0.05–0.07	.....
18	0.15	0.14	0.12	0.09
24	0.185	0.17	0.16	0.15
30	0.195	0.185	0.18	0.175
36	0.205	0.195	0.19	0.185

The lower plate spacings are usually dictated by economic conditions extraneous to those of column design proper, and are employed with special classes of materials. At the lower plate spacings, the characteristics of the liquid downflow have greater effect on performance due to height of foam or spray generated under operating conditions and hence specific experience becomes of increasing importance. In general, the table is considered to approximate conservative practice in petroleum and hydrocarbon distillation where tray spacings customarily range from 18 in. to 30 in., and operating pressures from 50 mm. mercury to 400 lb. per sq.in. absolute. Important deviations from these values are found in commercial hydrocarbon absorbers (absorption of C_3 to C_6 compounds with a heavier petroleum scrubbing oil), in which general practice appears to employ vapor velocities corresponding to 65-80 per cent of the K's of the table.

Examples of the use of Equation (1) in approximating design vapor rates for several oil fractionating towers are given herewith:

(1) Atmospheric topping tower — gasoline and steam overhead.

Pressure — Atmospheric
Temperature — 250 deg. F.
Vapors — 100 average M.W.
Liquid — 0.650 S.G. at 250 deg. F.
Plate spacing — 24 in.
Liquid seal — 2 in.
K (from table) — 0.16

$$d_2 = \frac{100 \times 492}{359 \times 710} = 0.193$$

$$d_1 = 0.65 \times 62.4 = 40.5$$

$$u = 0.152 \sqrt{\frac{40.5 - 0.193}{0.193}} = 2.3 \text{ ft. per sec.}$$

(2) Pressure distillate stabilizer, C_1 to C_4 overhead.

Pressure — 200 lb. per sq. in. abs.
Temperature — 155 deg. F.
Vapors — 49.1 average M.W.
Liquid — 28.6 lb. per C.F. at 155 deg. F.
Liquid seal — 1 in., plate spacing 24 in.
K (from table) — 0.17

$$d_2 = \frac{49.1 \times 200 \times 492}{359 \times 14.7 \times 615} = 1.49$$

$$u = 0.170 \sqrt{\frac{28.6 - 1.49}{1.49}} = 0.725 \text{ ft. per sec.}$$

(3) Vacuum column, gas oil and steam overhead.

Pressure — 50 mm. Hg.
Temperature — 350 deg. F.
Vapors — 164 average M.W.
Liquid — 0.681 S.G. at 350 deg. F.
Plate spacing — 24 in.
Liquid seal — 0.5 in.
K (from table) — 0.185

$$d_2 = \frac{164 \times 50 \times 492}{359 \times 760 \times 810} = 0.0183$$

$$d_1 = 0.681 \times 62.4 = 42.5$$

$$u = 0.180 \sqrt{\frac{42.5 - 0.018}{0.0183}} = 8.9 \text{ ft. per sec.}$$

(4) Cracking plant tower (receiving reformer and light gas oil cracking furnace discharges after tar elimination).

Gasoline and gas overhead
Pressure — 250 lb. per sq. in. abs.
Temperature — 450 deg. F.
Vapors — 75 average M.W.
Liquid — 0.626 S.G. at 450 deg. F.
Plate spacing — 24 in.
Liquid seal — 1 in.
K (from table) — 0.170

$$d_2 = \frac{75 \times 250 \times 492}{359 \times 14.7 \times 910} = 1.92$$

$$d_1 = 0.626 \times 62.4 = 39.1$$

$$u = 0.170 \sqrt{\frac{39.1 - 1.92}{1.92}} = 0.75 \text{ ft. per sec.}$$

Plate Spacings

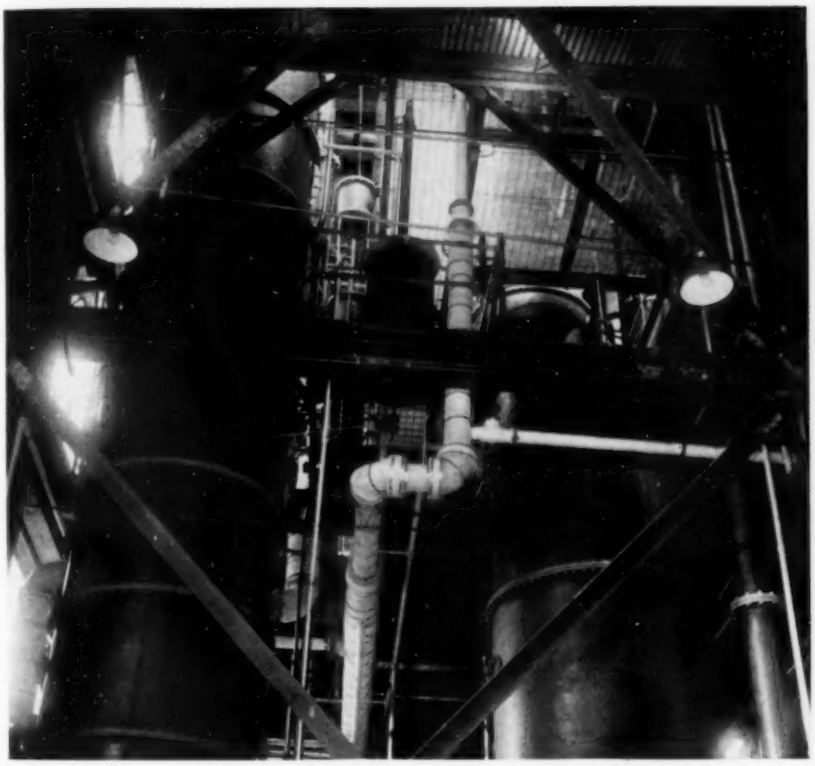
Plate spacings generally accepted as conventional in towers for specific services have been arrived at by the influence of factors related to performance and maintenance, together with the inevitable economic shakedowns which tend to standardize specialized equipment in general features. Columns which, for various reasons, are usually completely housed in buildings are frequently designed with tray spacings of 12 in. or less. These columns are often for sharp separations demanding a large number of plates; hence it is desirable to minimize height at the expense of cross sections. By proper selection of materials, this class of column usually requires little in the way of internal inspection and access. On the other hand, columns in the petroleum industry are not housed and present various degrees of internal cleaning, inspection and maintenance demands. Columns for the distillation of crudes and for cracking plant service usually are designed with plate spacings of 24 in. or more, permitting manholes between plates of sufficient size for removal of plate sections, and working space between plates. Plate spacings of 24 in. as compared with lower plate spacings for this type of towers do not impose economic burdens in tower cost, as the increased height is compensated for by the higher permissible vapor rates. The more rapid change of allowable vapor rates with plate spacing in the region of the lower spacings will lead to the conclusion that, considering column cost alone, larger plate spacings and smaller diameters would be more economical. Housing and other considerations frequently overbalance pure column design considerations for the lower plate spacings of 12 in. or less.

In general, as plate spacings are reduced, closer attention must be paid to cap submergences and foam or froth height upon the plate, as a greater proportion of the free disengaging area above the plate will be consumed by the presence of foam or an agitated liquid zone of considerable height. To a lesser extent, pressure drops must be watched to insure maintenance of the liquid downflow seal between plates.

Shape and Spacing of Caps

A wide variety of shapes and designs of bubble caps are to be found in commercial applications. In the larger capacity towers used in the petroleum industry, the principal types of caps used are the familiar round bell caps with diameters ranging from 4 to 7 in. and tunnel, or rectangular caps, of widths from 3 to 6 in. and lengths varying from 12 in. up. Both types are slotted around their lower periphery and are either anchored to the plate above the vapor raisers with teeth resting on the plate, or are suspended with adjustable levelling arrangements with the teeth clearing the plate. In general, the tunnel type caps require a smaller total number for a given slot and riser area, and hence present fewer parts to handle and adjust in assembling a tray. This may represent simplification of maintenance where frequent cleaning of trays is necessary. The older style round bell caps appear, however, to give better fractionating performance and are readily adaptable to variations in tray layouts without necessitating caps of two or more different sizes in order to obtain the desired cap slot and riser area.

Spacing between caps is a balance between an effort to obtain a large proportion of vapor riser and slot area and considerations of liquid flow on the plate, liquid depth (in turn related to weir capacities) and liquid rate of flow. The statement appears frequently in the literature that caps should be located sufficiently close for impingement of vapor streams from adjacent caps to obtain greater agitation and turbulence. At the higher vapor rates now used, it is recognized that too close spacing of caps may result in jetting or spouting action between caps, particularly with tunnel type caps with



Distillation equipment used in making ethyl alcohol and potable spirits

lengths of slots facing one another. This jetting action may project liquid or coarse spray to a considerable height above the plate and thus induce carryover.

Study of cap action in relation to liquid flow is frequently made using a full scale section of a plate (representing the complete path of liquid flow from inlet to outlet weir), and air and water as the vapor and liquid media. By this means, the effects of cap spacing as related to vapor rate, cap submergence and liquid flow can be appraised. As a result of the complicated relationships presented by cap spacing, it is possible to indicate only that the general range of spacings employed appears to be from 1 to 3 in.

Spacing of caps in relation to exit weirs has become recognized as of importance. With a large proportion of the caps on a tray adjacent to weirs, jetting or splashing over the weirs may materially reduce the liquid depth for which the tray was designed. If fairly stable froth or foam is produced on the tray under operating conditions, the flow over the exit weir may consist of this less dense material and result in a lowering of the effective depth on the tray. Hence in some cases it has been found desirable to provide a zone adjacent to the weirs in which no caps are placed, and which permits subsidence of foam and prevents jetting over the weirs.

Types of Liquid Flow

The simplest type of liquid flow with respect to the mechanical problems of tray and downspout arrangements is simple cross flow, in which the liquid travels from side to side in opposite directions on successive plates. By this arrangement all trays in a tower section can be of identical design, successive trays being installed in 180 deg. relationship. Downflows are segregated on opposite sides of the tower with no downflow piping manifolding consuming valuable disengaging space above the plates or interfering with access to the space between plates. Conditions which may limit this type of design are hydraulic gradients from inlet to outlet weir, or exit weir lengths obtainable with the weir located at one side of the tower. The problem of weir lengths is frequently solved by utilizing central exit weirs on one tray and side exit weirs on the following tray. Hydraulic gradients, which may cause uneven vapor distribution between caps, may be allowed for by varying the cap heights across the tray or by "cascade" design, interspersing distributing weirs at several positions in the liquid flow.

Weirs and Downspouts

This portion of plate design has demanded greater attention with the present use of pressure operation in which smaller tower cross sections are demanded by vapor flow, but in consequence of which liquid handling capacity may become controlling.

Overflow weirs of various shapes have been employed. One of the simplest, which is frequently used on smaller scale columns, consists of a circular weir with the downspout a continuation of the pipe representing the weir. In larger towers straight or slightly curved weirs are more frequently employed.

The recognition of the probable presence of foam rather than simple agitated liquid or trays in many operations had led to various provisions for foam disengagement before the overflow enters the downpipe proper. A simple illustration lies in the provision of a straight exit weir as a chord across the tower at one side. Behind this weir one or more circular pipes flush with the plate may operate as submerged orifices. The circular segment behind the weir permits disengagement space for foam before entrance of the liquid into the downspouts. These considerations of downspout capacity as limited by foam disengagement are apparently old in the distillation art, as recently [10] a patent disclosure of 1849 was noted in which the top of the downspout (and entrance weir) was a cup several times the diameter of the downspout.

In general, removal of liquid with low weir head prevents considerable variation in bubble cap submergence with variations in liquid flow. In general, weir heads (calculated on the basis of foam free liquid) up to 3 in. are frequently employed when the plate spacing is 18 in. or more. Simple crossflow trays with weirs on opposite sides can usually be laid out with exit weir lengths from 60 to 80 per cent of the tower diameter, and with maintenance of vapor riser and slot areas within recognized desirable minimum values.

For large vacuum towers in which liquid flow is low in relation to tower diameter, notched weirs are frequently employed to insure liquid

(Please turn to page 336)

Packed and Spray Type Contactors

BY Z. G. DEUTSCH, consulting chemical engineer of New York, N. Y., who for the past 20 years has been actively associated with heavy chemical industry. Much of his work has involved the design of stills, evaporators, columns, etc. for the Solvay Process Co., Mathieson Alkali Works and other companies.

DESIGN FOR OPERATION

EQUIPMENT CONSIDERED under the heading of this article has numerous uses. Not only is there much apparatus which consists wholly of packed or spray contacting chamber, but much more apparatus has parts or sections which are definitely of this form. Practically all examples of this class of chemical processing apparatus are "tailor-made" to suit the requirements of the specific job. A large part is fabricated from detail drawings, shipped piece by piece and assembled at the process plant without any outsider knowing what its use will be. Another large part is purchased as an assembly of more or less standardized part designs owned by equipment designers and builders who predict the performance. About the only well defined unique piece of equipment commercially available for this type of process is the ingenious Podbielniak "super-contactor."

There are a number of methods of classifying the equipment considered in this paper. Two methods, one based on the *use* of the equipment and the other on its *physical form*, are shown in the accompanying outline.

The common basic function of all is to provide contact between two fluid phases of greatly different densities so that a diffusion process proceeds in the most profitable manner. The designer of such equipment strives to have his conceptions achieve functional excellence by applying expedients which tend to:

1. Conserve reaction potential.
2. Produce more phase interface.
3. Promote intensity of contact.
4. Provide optimum conditions of time, temperature and pressure.
5. Permit adequate separation of phases at outlets.

These are the five commandments of contactor designers, whose usual methods in obeying them will appear as each is more completely defined and described.

Reaction Potentials

The designer considers that the materials entering the reaction, resist doing completely what he wants them to do. A definite driving force, or potential, is needed to carry the reaction to a definite state of equilibrium. A higher potential permits the reaction to come to the desired approach to equilibrium in a shorter time, or in a smaller space. This potential is usually called "driving force" (T. K. Sherwood: "Absorption & Extraction"). To the author, an electrodynamic analogy seems applicable. It is important to let none of the chemical voltage leak or short-circuit. As the electrical system is designed to maintain maximum available voltage where the work is being done, so should chemical contacting equipment be designed to maintain high potential between the reacting constituent. The diagram in Fig. 1 illustrates this conception. A common way of stating the above for a frequent case, is that the strongest freshest liquor. This generally calls gas should be scrubbed by the strongest liquor and the weakest gas by the for complete counter-current action. Fortunately, all usual liquids have densities so much higher than usual gases, that this is easy to accomplish gravitationally.

Attempts by the designer to prevent or inhibit all short-circuiting and channeling are generally more related to commandments (2) and (3) than to this one. He strives for a methodical flow of gases up through filling materials and a slow showering of the liquid phase over filling materials by proportioning areas so that no too-dilute liquid contacts strong gas. In the spray type equipment. solutions are collected at intervals and returned, so as to make concentration changes in the spray medium methodically step-wise.

The first duty, therefore, is to obtain the equilibrium data, the ther-

Contacting equipment may be classified in two general ways. They are as follows:

I. Classification based on use of equipment

A. Treatment of gas phase
1. Purification
   a. Removal of minor constituents. Examples: Sweetening natural gas; removing dust from kiln or furnace gases.
   b. Humidification and dehumidification. Examples: Drying chlorine from cells with sulphuric acid; air conditioning.
2. Separation
   a. One highly soluble constituent. Examples: NH_3 in water; hydrogen chloride in water.
   b. One slightly soluble constituent. Example: oxygen in water.

B. Treatment of liquid phase
1. Reaction. Example: Solvay tower
2. Distillation. Example: CO_2 from ethanolamine carbonates
3. Cooling. Example: Condenser spray water cooling towers

II. Classification based on physical features of equipment

A. Packed vertical towers
1. Stone, coke or mineral packings
2. Metal packings
3. Ceramic packings
4. Wood slat and other organic packings

B. Spray type contactors
1. Vertical towers
2. Horizontal chambers
3. Spray ponds

C. Wetted wall contactors
1. Wetted wall towers
2. Podbielniak contactor
3. Tourills

mal data and the diffusion rates involved in the reaction and to determine therefrom which of the resistances (to complete and instantaneous diffusion) is controlling at each of several concentrations which will obtain in the equipment. This determines whether or not the apparatus is to be of essentially uniform cross section, and whether a single compartment is suitable and if not, what the approximate number of compartments must be.

If the equilibrium data are not available in the literature, laboratory or semi-plant test work is generally undertaken. Occasionally the problem at hand is sufficiently analogous to one already thoroughly explored or sufficiently understood to make final development of design in the actual plant, the most profitable procedure.

More detailed considerations of this fundamentally theoretical aspect of design, is beyond the scope of this paper. Quite adequate literature is available on its principles and practice.*

Phase Interface and Intensity of Contact

These two aspects of design involve quite distinct concepts, but in the great majority of actual cases, sufficiently accurate data are not available to the designer to permit him to base his design for control on one of them separate from the other. Since they are generally treated together by designers, they are discussed together here.

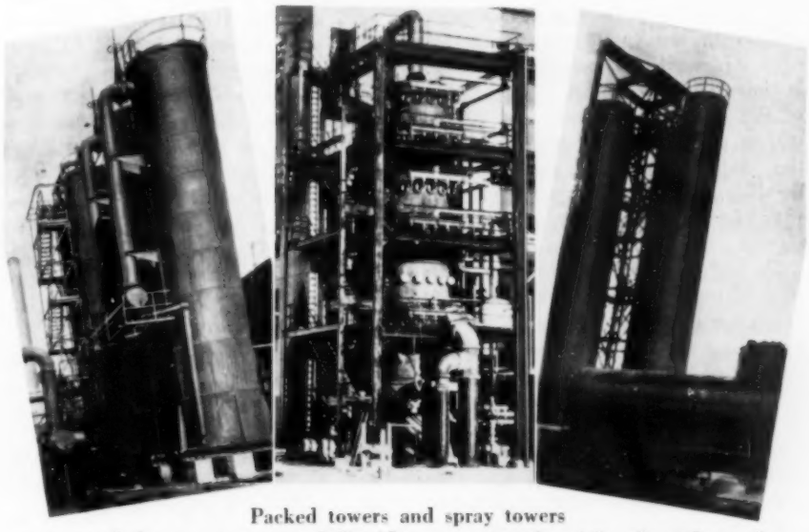
To obtain a better grasp of the separate concepts and how they are combined by designers, consider the absorption of a gas in a liquid in which it is readily soluble. If the work is being done in tourills, obviously any changed performance with a greater or less number of tourills of the same size in the series, can only be due to increased or reduced surface for contact, or a change in "the extent of phase interface."

If, however, comparison of a vertical tower filled first with 5/8 in. raschig rings and then with 1 in. Berl saddles shows a very appreciable difference, the deduction is not so simple. The two have very nearly the same amount of "geometric" surface per cubic foot of packed space. For non-porous ceramics this is generally accepted as tantamount to equal phase interface, but it is not actually so and there is no rigorous way to determine the relative amounts of phase interface. The "per cent free space" of the saddles is about 70 and of the rings only 54. This suggests reasons for a difference in performance. The time that it takes liquid to fall through the tower can be expected to be different. Also the velocity of rising gas, relative to descending solution, is different. It is higher for the materials with the lower percentage of free space, considering the same gas weight. Pressure drop will be different likewise, bringing about a higher initial potential and higher power consumption for the raschig rings with equal gas weights. The effects and magnitudes of pressure drop and contact time can be determined in separate equipment, but areas can only be estimated for regular packing shapes and crudely guessed at for irregular shapes, sprays and for bubbles of gas rising in liquid-filled towers. Comparisons are therefore possible only by combining a number directly related to area, with some other number which is related to the intensity of contact.

The importance of these effects on the design of the equipment is, to a large extent, related to the work to be performed. They are not very important where a reaction proceeds very readily to completion, but are all-important where the opposite is true. In general they are not the expensive features for the designer to build into his equipment. Four physical methods are described here.

Sprays—The use of sprays which divide the liquid phase into a large number of high area-to-weight-ratio particles traveling at fairly high speeds through the gas, is inherently more suitable for absorbing very soluble gases. This type equipment is not as popular as the large amount of interface obtainable in that manner would seem to dictate. This is probably due to the fact that sprays are frequently troublesome pieces of equipment. The relatively high velocities erode nozzle orifices and, since a small amount of erosion or corrosion decidedly changes characteristics of a nozzle, this makes for high maintenance. Secondly, this type of equipment is sensitive to solid foreign matter in the liquid. Thirdly, in cases where large concentration changes in the liquid are involved (usually the case with highly soluble gases), numerous collecting trays and redistributing nozzle banks, each with separate pumps and more or less involved circulating systems, are required.

Bubbling Towers—The method of bubbling gas through a column of



Packed towers and spray towers are used for many types of liquid-to-gas contacting jobs throughout the chemical process industries. In every case the successful operation of the tower depends upon the multitude of refinements in the equipment provided by the designer

*Walker, Lewis, McAdams and Gilliland—Chapters XIV, XV, XVIII; Lewis & Randall—Chapters XVI, XVII and XVIII; T. K. Sherwood—Absorption and Extraction; etc. all have good bibliographies.

liquid is inherently more suitable for absorbing less soluble gases. Due to the expense involved in breaking up and redistributing coalesced gas bubbles (which is the principal design problem) and in compressing large gas volumes, it finds application only where it has some corollary advantage, as in providing agitation needed for catalyst suspension in the hydrogenation of fatty oils or for formed precipitates as in the Solvay tower. It is an especially advantageous method in rare cases when gas-lifting of a corrosive liquid can be accomplished at the same time the absorbing is done.

Wetted Wall Towers—The wetted wall type of contactor is seldom used and is in reality a sort of special case of a filled or packed tower. It is used where the dust burden of the gas or precipitation of solids taking place more or less slowly in the liquid, would cause fouling troubles. It does not provide much play for the ingenuity of the designer.

Packed Towers—The filled, or packed type of tower is widely used. It extends the phase interface by spreading the liquid phase over the surface of ceramic or other materials which are either inherently porous or finely divided in themselves. It causes intimate contact through turbulence of the tortuous gas passage. Some very inexpensive filling materials are used for most large volume towers, where the resulting added size of the equipment is much less costly than the greater interface available in ceramic or other uniform prepared materials. Among the inexpensive materials, coke is probably the most popular. Its excellent performance is attributable to the high porosity of the lumps and also probably to the roughness of the surface of each lump. It has a very wide field of application because of its insolubility in almost every material handled by chemical plants. Its gradual deterioration due to individual lumps breaking up and the fine particles washing down into undesired spaces, is its principal disadvange as a tower packing.

A popular form of packing is limestone or other quarried material chosen principally for its inertness under the specific conditions considered. Obviously limestone is used only when a large excess of CO_2 is present; high silica rock is used if no caustic is present, etc.

These cheapest kinds of packing find an important application where gradual fouling with insoluble precipitates or solid impurities requires a material that may be inexpensively replaced.

Another inexpensive filling material which is finding favor is scrap from various kinds of metal working operations. Lathe turnings and punchings from power press operations are possibly the cheapest materials with a reasonably large amount of phase interface and low retention characteristics.

Some prepared metal filling materials are on the market or have been made specifically for certain applications. These consist of small castings such as three discs at right angles to each other, press-formed units similar to raschig rings, or woven nettings. In general the unit cost of these is high compared to the ceramic materials, but they have a very high free space and consequently much interface for low pressure drop. Where the enclosure of the equipment is expensive, due to such a circumstance as operating under 100 or more atmospheres pressure, the most efficient filling material obtainable is justified.

Many distinct shapes of ceramic materials are available, ranging from the simple raschig rings through those with special kinds of webs inside of them to the Berl saddles (which can only be described with the accompanying photograph). The regular ceramic shapes have a decided advantage in certain applications where avoidance of lateral pressure is desired.

The manufacturers of these can furnish convenient data concerning geometrical characteristics and measurements but have little of value regarding pressure drop. Even the relative pressure drops among various sizes and forms made by a single manufacturer, are not included in catalog data. Some isolated groups of performance figures have been published but no correlation satisfactory to this writer has ever come to his attention.

The designer generally assumes that materials of the same essential size and free space are equal and he estimates pressure-drop on the basis of experience with an analogous equipment. His design ingenuity is called into play principally to get the best liquid distribution and sufficiently frequent redistribution, which are extremely important in towers of large cross-section.

Many designers believe that packing near the center should be larger than that at the walls, rather than uniform packing with redistributors placed "at short intervals" down the walls.

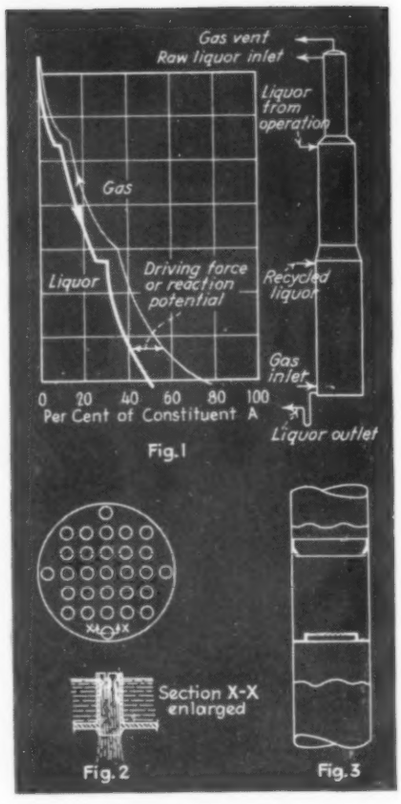


Fig. 1 illustrates the driving force variation in a packed tower, Fig. 2 shows a feed distributor plate in cross-section, and Fig. 3 shows two different types of liquid redistributors

Feed Distributors

To get uniform distribution, feed plates such as illustrated in Fig. 2, are most commonly used. The designer refines the performance of such distributors with: (1) Multiple feed inlets to the plate to minimize effects of hydraulic gradient, (2) Flared inlets to minimize mal-distribution due to entrance velocity-head, (3) Machined weir notches, (4) Leveling screws, and (5) Machined drip lips below each pipe.

Similar plates are used to redistribute liquor at intervals down the column, but such require a grate to support the packing above and thus use up some "packed height." A short inverted truncated cone or a channel is illustrated above in Fig. 3 eliminates that loss but does not do as

thorough a job of redistribution. When packed height is limited by the strength of packing itself, a combination of the two is advantageous.

The provision for optimum conditions of time, temperature and pressure is, of course, a design problem not peculiar to liquid-to-gas contacting equipment. It involves specification of the amount of heating or cooling surface, the heat insulation, and the thickness of shell to prevent bursting or to avoid collapse. The design details involved in these requirements are, of course, related to the others and must finally be considered with them.

Separation of Phases at Outlets

On the liquid outlet end of a piece of contacting equipment a syphon type of U-seal for low pressure work or a float-operated drain valve is necessary. On the gas outlet end, the designer faces a more serious problem. Often the liquid constituent is too valuable to permit small droplets to be wasted with the exit gas, or it may be that the exit gas is valuable and may not be contaminated with any liquid entrainment. Hence the problem involves the design of an adequate disengaging chamber, and numerous empirical as well as theoretical (Stokes' Law) formulas are available to the designer. Some types of filling materials, such as metal netting, are available and recommended for breaking up foams which are sometimes encountered. Sudden velocity change (either in direction or magnitude) is the basic principle underlying design of liquid-gas disengaging apparatus.

Other Features of Design

In addition to the features of design which permit the apparatus to function in accordance with its chemical duty, there are other important requirements. These can be divided into two groups: (1) those which promote operating expediency, and (2) those which promote low maintenance expense. In some cases these two items can be more important than strictly functional considerations.

Process equipment may have the advantages of its technical excellence neutralized by the inconvenience and awkwardness of operating it. The first need of gas-to-liquid contacting equipment (because of its generally skyscraper proportions) is to provide for central control. That is, all valves which must be opened, shut or throttled for starting, stopping or controlling the operation need extension handles or push-buttons for that purpose concentrated in a small area and, more important, at one level. Besides merely bringing the handles or push buttons into a concentrated area at one level, the designer should consider the relationship of these handles to each other and visualize the operator's job in learning what each means and the potential confusion of a haphazard arrangement. In general the valve handle or push button should be immediately adjacent to some sort of indicator which shows the operator what he has done by shifting the handle, lever or push button. This can be either a direct indication such as a pointer along a quadrant or scale, or it can be a resultant indication, e.g., if a valve has been moved to raise a temperature somewhere, the indication can be a thermometer of some sort. All indications of temperature, pressure, flow rates, etc., which are important to the operator for the control (as distinct from history) of the operation, are needed at this same station.

Frequently these devices involve such simple things as small permanently mounted telescopes with which to see remote glass-stem thermometers, pressure gages or gage glasses. A general principle in connection with this type of instrumentation is that utmost simplicity should be provided the first time. Complication should only be added by operators after considerable experience shows the need for such.

Control of the operation generally requires sampling at several points and some kind of test or analysis by the operator. Pipe lines for delivering such samples to the control station or the adjacent testing equipment are a requirement of first class operation. The designer of the apparatus needs to visualize the complete test; he must base his conclusions on the fact that such tests are to be a help to, rather than disciplinary duty of, the operator.

Floor or scaffold levels, which give access to all parts of the apparatus, can best be arranged by the designer specifically for that purpose; that is, if he is designing the apparatus to fit an existing building, he should be prepared and willing, if profitable, to alter the ideal functional dimensions to suit floor levels. If he designs a building to give access to a big piece of contacting equipment, he does well to consider the needs of the apparatus foremost. A general principle to have in mind when designing a building for the apparatus (or vice versa) is that the building is only an access scaffold on which a weather shelter is to be hung.

An important (but very frequently neglected) feature of design has to do with minimizing the disastrous results of occasional maladroit operation. If, for example, the most likely occurrence which can result from "out of control" due to operating inattention is the entrainment of a large amount of liquid over the top, then a catch-all or "extra" entrainment disengaging device needs to be installed. If operating pressure will be the most sensitive control, the necessary needle valves and "anticipating" pressure indicators need to be provided. The designer does well to say to himself, "If the attendant dies of heart failure, what is the first thing that will hap-

(Please turn to page 336)

Berl saddles are made in many different sizes and of many different materials. Here are saddles of aluminum, chemical stoneware, graphite, porcelain, etc. The smallest shown here is the ¼-in. size

Cost Relations of Heat Exchangers

BY E. N. SIEDER, manager of the Heat Exchanger Division of Foster Wheeler Corp., New York, N. Y., who has been engaged in testing, designing and sales engineering work relating to heat exchangers for 14 years. In addition to writing numerous articles on heat exchanger design, he has conducted a course in the subject at Columbia University for the past three years.

DESIGN FOR OPERATION

THE WEALTH OF TECHNICAL PAPERS, test reports, hand books, etc., that have been published in the last ten years dealing with the design of heat exchangers has made it appear possible for an engineer to determine the size of such equipment needed for his requirements. However, those who have attempted such a task without the benefit of previous experience will agree that it is a job best left to the experienced technicians regularly employed in the manufacture of heat exchange apparatus. On the other hand the prospective buyer, finding himself in need of heat exchange equipment can save time and money by preparing a specification outlining his requirements from both a process and mechanical point of view.

The process requirements will probably be unique with each buyer, or for each type of service, and in any case will best be known by the prospective user. His requirements from a mechanical standpoint, however, might be met by a variety of types and arrangements of heat exchange equipment; it is here that long experience and standardization of acceptable designs will help the user select the equipment best fitted for his needs.

It is the purpose of this paper to show how variation in physical dimensions and mechanical standards will affect the performance and cost of shell and tube heat exchange equipment. An outline of the important features which are subject to variation between different designs should include types, bundle data and construction data as indicated in the tabulation in an adjoining column.

Important Features Influencing Design of Heat Exchangers

Types
- (a) Fixed tube sheet vs. floating-head, removable bundle.
- (b) Horizontal vs. vertical.

Bundle data
- (a) Tube length.
- (b) Tube diameter and gage.
- (c) Tube arrangement or pitch.
- (d) Baffle types.

Construction data
- (a) Shell and tube safe working pressure.
- (b) Code construction requirements.
- (c) Material specifications.

Choosing between the fixed tube sheet and the floating-head removable bundle type of heat exchanger should not be difficult. The fixed tube sheet type is usually ruled out because of differential expansion between shell and tube. Its use should be limited to cases where the maximum differential temperature between shell and tube does not exceed 50 deg. F. Special cases might require a fixed tube sheet unit with a special expansion joint provided in the shell.

The floating-head, removable bundle type is recommended for most services and because its tube bundle is readily removable, should prove to be the most economical selection in the end. The choice between vertical and horizontal installations will depend on the plant layout, personal choice or, in some cases, on process requirements. The choice of horizontal or vertical units will seldom affect the first cost of the equipment.

Choosing the proper tube size, length, arrangement, etc. will probably be the hardest determinations for the buyer to make. These design features are subject to more variation than perhaps any others and in their variation we find the greatest differences in first cost.

Serious thought should be given this phase of the specification and a decision arrived at only after consideration has been given to such factors as:

1. Type of fluid to be handled, clean or dirty?
2. Cleaning means to be used, if any.
3. Temperature encountered in service and under shock conditions.
4. Space limitations.
5. Tube stock and standardization program covering the entire plant.

When selecting the proper tube size we find that the following standard diameters are in common use: $\frac{5}{8}$, $\frac{3}{4}$, 1, $1\frac{1}{4}$ and $1\frac{1}{2}$ in. From this assortment can be chosen a size best fitted for almost every service. The tendency with large buyers of heat transfer equipment is to standardize on one, or perhaps two diameters. One of the larger oil refiners has standardized on 1 and $1\frac{1}{4}$ in. tubes. Several others use only $\frac{3}{4}$ and 1 in. O.D. tubes.

The small tubes when used in heat exchange equipment have in their favor low first cost and higher efficiencies when clean. The larger tubes are used where the fluid to be handled is of a fouling nature. The large tubes may be cleaned more easily and do not show a decrease in heat transfer efficiency as rapidly as small tubes when subjected to fouling conditions.

We find only two tube arrangements available commercially, trian-

gular pitch (tubes arranged on equalateral triangles) and square pitch. In either case the clearance between tubes should not be less than one-fourth the tube diameter and in no case less than $\frac{3}{16}$ in.

In general we may say that tube bundles made up with tubes arranged on a triangular pitch are not cleanable on the outside of the tube surface. This type of bundle is not recommended except where the fluid is definitely known as nonfouling. Steam, condensate, clean naphtha vapors and pure, or highly refined liquids may be included in this class.

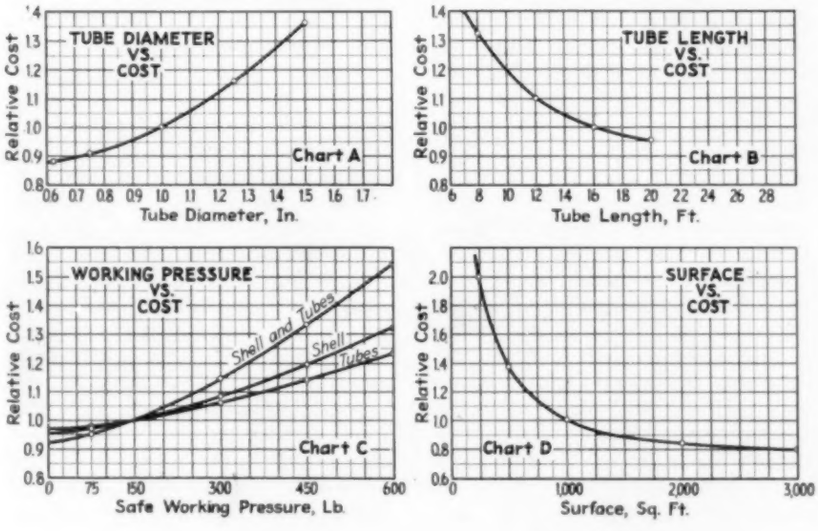
When there is any doubt regarding the suitability of triangular pitch or where the fluids to be handled are of a fouling nature, a square (cleanable) pitch should be specified. A large buyer of heat exchange equipment, having in mind both fouling and nonfouling service, would do well to standardize on the square pitch. Such a far sighted policy will pay dividends in adaptability of equipment and reduction in number of extra tube bundles required for replacement.

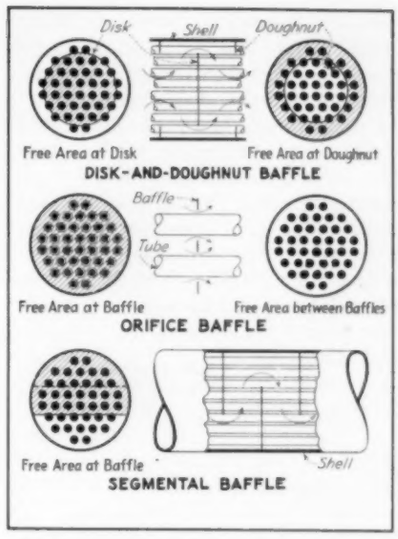
Price Considerations

It is of great importance to anyone writing specifications to know the effect that his choice of tube size, tube length, arrangement, etc., will have on the price of the equipment he is to buy. Let us consider the tube size first. Referring to Chart A, we see a curve showing the relative cost of heat exchange equipment with varying tube sizes. A 1-in. O.D. tube is taken as the standard and its price is considered to be unity. It may be noted that the price of the equipment will increase less than 5 per cent when going from $\frac{5}{8}$-in. tubes to $\frac{3}{4}$-in. tubes and less than 10 per cent when going from $\frac{3}{4}$ to 1-in. tubes. However, the use of larger tubes, such as $1\frac{1}{2}$-in., will result in a price increase over 1-in. tubes of 35 to 40 per cent. The very slight saving in first cost obtainable when using $\frac{5}{8}$-in. tubes would hardly warrant their use when we consider the trouble encountered in keeping a bundle with small tubes in a satisfactory operating condition.

Effect of tube length on the price of tubular heat exchange equipment is shown on Chart B. Here we have taken a 16-ft. length of tube as the standard and have considered the cost of such a unit as unity. The use of a 20-ft. tube will result in a decrease in price of less than 5 per cent. The use of a 12-ft. tube will only increase the price about 10 per cent. A buyer of heat exchange equipment would do well to standardize on perhaps two tube lengths, 12 ft. and 16 ft. The longer tubes are to be used where the units are placed near the ground and expensive steel platforms and equipment for bundle removal are not required; the 12-ft. lengths are to be used for shell and tube equipment located high up on steel work or where long tube bundles would complicate the arrangement of the layout.

A prospective buyer of heat exchange equipment must consider a great many different variables when writing his specifications. Certainly one of the most important considerations is cost. Here are shown the relations between cost and tube diameter, tube length, working pressure and surface





There are three systems of transverse baffling—orifice type, cross flow type and support plate type. Free areas in orifice and two kinds of cross flow baffling are shown above

Aside from space limitations we find that the shorter tubes are less subject to distortion where high temperatures or severe temperature shocks are encountered. This reason alone has caused several large refiners to standardize on 10- or 12-ft. tubes.

Design of Baffles

Choice of baffle design or type will vary with different designers or manufacturers. It would be well, however, for the buyers to be acquainted with the several types available and to understand their advantages and limitations.

Transverse baffling systems can be divided into three classes—orifice type, cross flow type and support plate type. Orifice baffles are full circular in shape and rely, for their effectiveness, on small apertures between or around the tubes through which the fluid squirts at high velocity. To be effective this type of baffle must fit the shell snugly and should be spaced on close centers. The orifice type of baffle is not suitable where fluids of a fouling nature are to be handled as the small apertures rapidly plug up to cause increased pressure loss and lower heat transfer rates. Corrosive fluids will quickly destroy a tube bundle made up with orifice baffles.

The cross flow type of baffle including the segmental and disc-and-doughnut types is recommended for most

services. It need not be on extremely close centers and does not require a machine fit between the periphery and the inside of the shell to be effective in promoting heat transfer. As fewer baffles of this type are required they can be made of heavier material insuring a more lasting and rugged structure. Fig. 1 illustrates the several types referred to above. For setting up the specifications the following minimum thicknesses are recommended:

Shell I. D. (Inches)	Thickness of Baffle (Inches) Baffle Spacing Under 12 in.	Baffle Spacing 12 in. and Over
4–9	1/8"	3/16"
10–23	3/16"	1/4"
24 and over	1/4"	1/4"

Full circle or semi support plates are usually supplied in lieu of baffles to support the tubes when heat transfer or pressure drop calculations make the latter unnecessary or inadvisable. Tubes should be supported at least every 75 diameters.

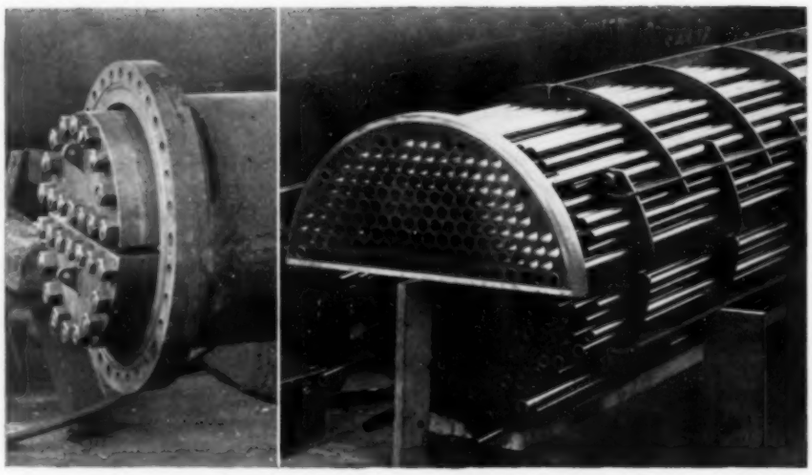
No specification covering baffling would be complete without reference to longitudinal baffles. These baffles may be classed as the welded type (permanently fixed to the shell) and removable type. Except for certain short types of diffuser plates all removable baffles should be arranged to make a tight seal at the shell. The method of sealing should be considered carefully from the standpoint of effectiveness, permanence, ruggedness and its ability to remain effective under conditions of corrosion.

Whether the longitudinal baffle is of the welded or removable type its use should be limited to conditions where temperature variations or temperature shock are not severe unless special provision is made to take care of such conditions by the use of multi floating heads.

Empirical Formula for Number of Floating Heads

$$(T_h - t_c)\left[\frac{(\Delta t\ max.)}{(\Delta t\ min.)}\right]^{2/3}\frac{LW}{NP^{1/3}} = <1{,}000{,}000$$

T_h = inlet temp. deg. F. hot fluid
t_c = inlet temp. deg. F. cold fluid
Δt_{max} = max. temp. diff. between shell and tube fluid
Δt_{min} = min. temp. diff. between shell and tube fluid
L = tube length in inches
W = shortest dimension of the floating tube sheet
N = number of floating head
P = number of passes per floating head



Left—Floating heads of a heat exchanger. Two floating heads in a single shell increase the cost approximately 30 per cent over cost of one head. Right—This view of an unfinished heat exchanger shows how the tubes are mounted and also the arrangement of the baffle assembly

In too many instances the buyers' specifications leave the responsibility for determining the proper number of floating heads up to the manufacturers or designers. If the buyer is not in a position to check his requirements concerning the proper number of floating heads by past experience he would do well to check the proposed designs against the accompanying empirical formula.

This should eliminate the possibility of purchasing a piece of heat exchange equipment which will eventually fail if severe temperature variations or shocks are encountered in operation.

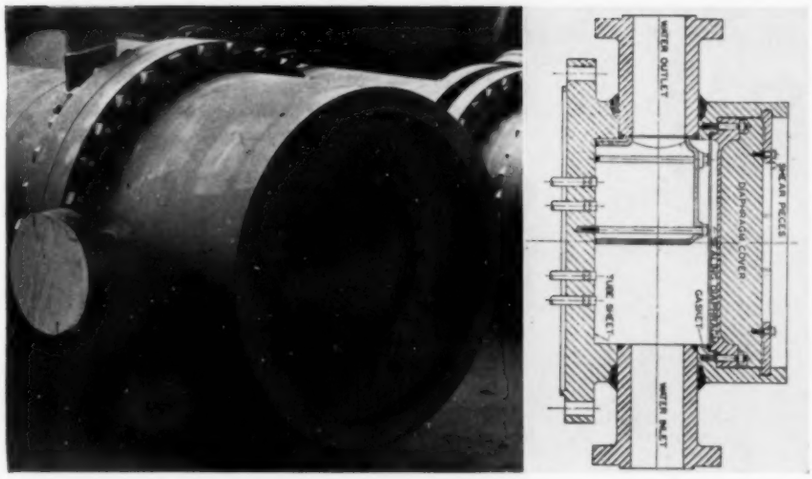
The use of the two floating heads in a single shell will increase the cost approximately 30 per cent over that of a unit with one floating head. Four floating heads in a single shell will cost approximately 50 per cent over one floating head. The use of two floating heads in a single shell is somewhat better from the differential expansion standpoint than two shells each with one floating head. This is evident also from the formula.

Design of the bolted joints in an exchanger may be considered an unimportant detail by some, but the experienced buyer and designer will not skip over this detail lightly. Where high pressures and temperatures are encountered or where the fluids to be handled are of an explosive or lethal nature bolted flange joints should be made up with metal, or metal jacketed gaskets held firmly in place by grooves or recesses in the flanges. Alloy bolts should be specified for all pressure joints. Such bolting should at least conform to ASTM Specification A-193.

Design of Flanges

Design of the flanges should be based on some competent authority. Such a reference would be "Modern Flange Design" published by Taylor Forge of Chicago. Where large flange joints are subject to high pressures (600 lb. or more) the buyer would do well to consider some successful form of sealing or locking device for the removable covers other than the conventional bolted joint. Two general types are available. One type depends on the inner pressure to maintain a tight gasket seal. The more dependable type employs a separate means, such as a sealing diaphragm, independent and unaffected by internal pressure. A good illustration of the latter type is shown on page 325.

Most manufacturers of heat exchange equipment carry several standard lines for different safe working pressures. In general these pressures will be 75, 150, 300, 450 and 600 lb. per sq. in. In preparing specifications for new equipment a saving in price will usually result from adherence to these standards. Chart C shows the approximate variation of cost with safe working pressure. This chart shows further the variation in cost when either tube or shell pressure is changed and when both are changed.



Where large flange joints are subject to high pressures (600 lb. or more) a locking device other than the conventional bolted joint should be employed. The photograph and drawing above illustrate one such type of locking device which uses a sealing diaphragm unaffected by internal pressure

A unit having a safe working pressure of 150 lb. per sq.in. on both shell and tubes is used as a standard and its cost is considered to be the base price. Units designed for 75 lb. per sq.in. safe working pressure will show a saving of about 5 per cent over those designed for 150 lb. per sq.in. The increase in cost for 300 lb. per sq.in. over over 150 lb. per sq.in. equipment would only be about 14 per cent. The probable saving in first cost by the use of a number of standard pressures will hardly be worthwhile in the smaller sizes, but may be appreciable in the larger units. It might be well to standardize on 150 lb. per sq.in. and 300 lb. per sq.in. units up to and including 1,000 sq.ft. per shell. Above 1,000 sq.ft. the 75 lb. per sq.in. might well be introduced.

Allow for Corrosion

Whether or not corrosion is expected in the heat exchange equipment under consideration, a certain corrosion allowance should be specified for all ferrous parts with the exception of baffles and tubes. It is probably safe to say that standard heat exchangers may be purchased which include at least ⅛-in. corrosion allowance, at no extra cost. Above an eighth of an inch it may be assumed that the cost of an exchanger will increase about two per cent for each ¼-in. of corrosion allowance required.

The careful buyer when outlining his requirements covering heat exchanger apparatus will usually specify that the design and construction should follow one of two codes, API-ASME or ASME. Or he may be required by law to have his equipment inspected and approved by a national inspection agency or underwriter. Little or no increased cost should be expected when specifying API or ASME code requirements as most large manufacturers design to these code requirements as standard practice. Exchanger equipment destined for the oil refinery should conform to the API code and equipment for use in boiler rooms or power plants should conform to the ASME code.

The matter of hydrostatic test will be suitably covered by referring to either of the above mentioned codes. In any case the specifications should call for a hydrostatic test on both shell and tube sides of the unit to 1½ times the safe working pressure. In cases where the design temperatures are higher than 650 deg. F., the cold test pressure should be suitably increased in order to ascertain that the unit has the required 50 per cent safety factor under operating temperatures.

Included in the specifications with items of a general nature might well be inserted a note as to the maximum allowable size of a single shell and tube exchanger. Reference to Chart D will show that the economical limit in surface lies between 2,000 and 3,000 sq.ft. per bundle, or a maximum of 48 in. shell diameter, which would represent 2,000 sq.ft. of 1½-in. tubes 12 ft. long or 3,000 sq.ft. of 1-in. tubes 12 ft. long.

A worthwhile addition to the final specifications would be a table outlining the specifications governing the material entering into the fabrication of the heat exchangers. Such a detail table may be found on page 11 of the "Standards of the Heat Exchange Institute Tubular Exchanger Section." An extract from the table including the more regularly used materials is included herein.

Specifications Governing the Materials Entering into the Fabrication of Heat Exchange Equipment

Shells

Carbon steel plate	ASTM A-70
Lap welded pipe	ASTM A-106, A-53, API 5-L
Seamless steel pipe	ASTM A-106, A-53, API 5-L
Cast iron (semi-steel)	ASTM A-48-Class 30

Covers, Shell

Carbon steel plate	ASTM A-70
Cast iron (semi-steel)	ASTM A-48-Class 30
Carbon steel cast	ASTM A-95

Covers, Channel and Floating

Carbon steel plate	ASTM A-70
Carbon steel cast	ASTM A-95
Cast iron (semi-steel)	ASTM A-48-Class 30
Bronze, cast	85-5-5-5

Channels

Carbon steel forged	ASTM A-181-Class 1
Carbon steel cast	ASTM A-95
Cast iron (semi-steel)	ASTM A-48-Class 30

Flanges

Carbon steel forged	ASTM A-181-Class 1
Carbon steel rolled	ASTM A-70

Nozzles

Carbon steel forged	ASTM A-181-Class 1
Carbon steel fabricated:	
From pipe	ASTM A-106, A-53, API 5-L
From rolled plate	ASTM A-70

Clamps, Rings, Etc.

Carbon steel forged	ASTM A-181-Class 1
Carbon steel rolled plate	ASTM A-70

Bolting Material

Alloy steel	ASTM A-193
Above 160 lb. per sq. in. and Above 450 deg. (1,000 deg. F. Max.)	(At least equal to Class B material)

Tube Sheets

Carbon steel	ASTM A-181-Class 1 ASTM A-70
Naval brass	U. S. Navy 46-B-6

Baffles and Support Plates

Carbon steel	Commercial tank quality steel plate
Naval brass	U. S. Navy 46-B-6

Spacers and Tie Rods

Carbon steel	Steel line pipe and commercial carbon steel
Brass	Commercial brass pipe and rod

Tubes

Carbon steel	AASM No. 300	Average wall thickness
Chrome alloy, 4–6 per cent	AASM No. 350	
Intermediate chrome molyb	AASM No. 352	
Admiralty	ASTM No. B-44	
Cupro nickel	70–30, 80–20	
Nickel, aluminum bronze	92–4–4	

Designing Heavy Rotary Equipment

BY W. S. DICKIE, engineer in charge of cement, lime and chemical equipment, Vulcan Iron Works, Wilkes-Barre, Pa. Starting professional life as a civil engineer, Mr. Dickie later was for some time manager of one of the American Car & Foundry plants. For the past 22 years his activities have been as indicated by his present title.

DESIGN FOR OPERATION

Design of heavy rotary equipment such as kilns, coolers and dryers appears to depend more on experience than is usual with most process equipment, since handbooks and other literature sources contain little worthwhile information on which design can be based. It is up to the designer, therefore, to draw on his special knowledge in determining the necessary size of equipment for the required output, so that it may be produced at minimum cost, and to determine the sizes and other design features of the various component parts making up the complete machine. It must be recognized that a wide variety of conditions may be met. For example, both wet and dry materials are treated in such equipment, materials of widely varying lump and particle sizes, and materials which may become liquid or semi-liquid as they are treated. Another difficulty is the possibility of maltreatment of the machinery, not necessarily because of ignorance on the part of the operating force, but because of conditions beyond control. Only a long period of trial will show whether the machine is properly designed and whether it is as nearly foolproof as possible.

Although such rotary equipment is used to by far the greatest extent in the cement industry, its development was pioneered in the treatment of black ash and the production of alkali. It was considerably later that the cement industry adopted the rotary kiln, but from that time rapid progress was made in design and in the determination of proper equipment size. Other chemical and metallurgical industries have gone to equipment of this type, realizing its advantages in continuity of operation and low operating cost, in contrast to batch equipment. Some of its uses might appear strange, were it not for the decidedly favorable cost figures it has shown.

Kiln Shell

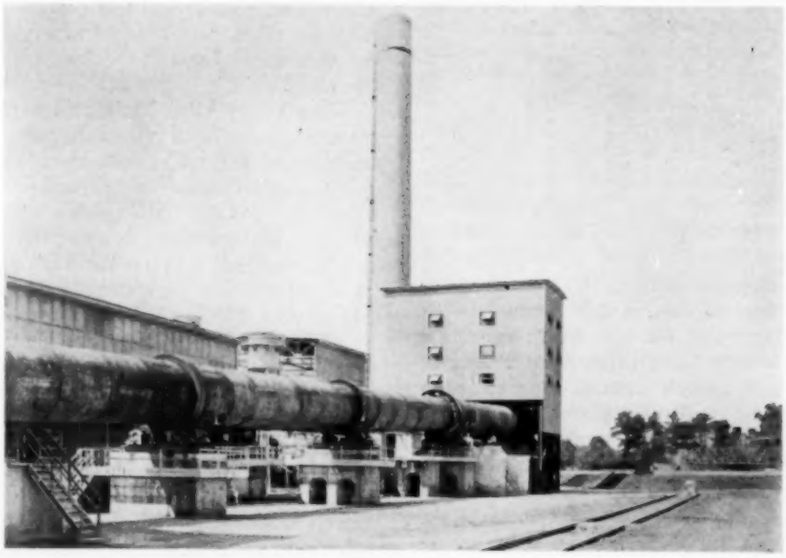
The rotary kiln, as used for cement making, is definitely divided into zones throughout its length. For wet operation the feed zone at the cold end of the kiln is the drying zone. This is followed by preheating, calcining and finally the clinkering or burning zones. In a dry-process plant the drying zone is unnecessary. In the burning of limestone or other materials which are dry when fed to the kiln, the zones are the same as in the cement kiln for dry operation. Usually, however, such materials as limestone are fed to the kiln containing a certain amount of natural moisture and a short drying zone is therefore needed. Several schemes have been proposed to facilitate the drying of wet feeds and thus allow a shorter length of kiln, some of which are in use.

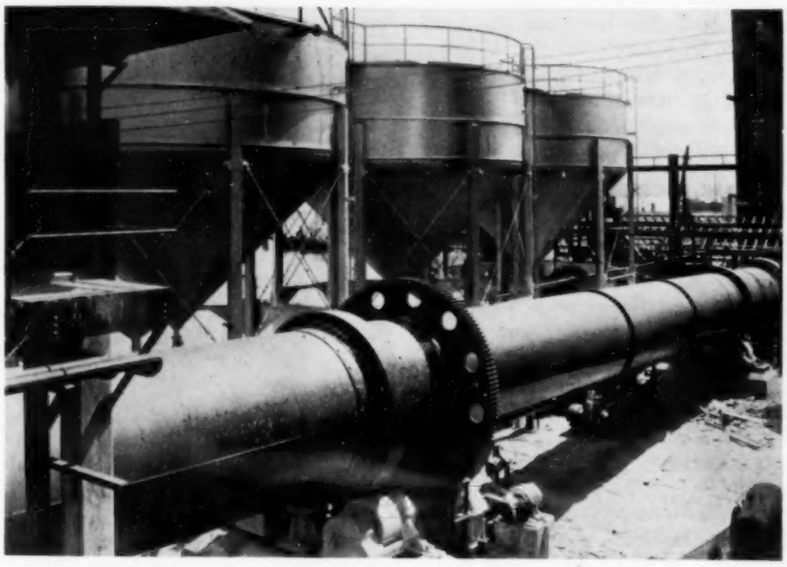
Broadly speaking, the function of kiln diameter is one of capacity, while the length governs efficiency. Although some transfer of heat doubtless takes place from the heated brickwork to the charge, most of the productive work done in heating the charge flowing through the kiln consists in the transfer of heat from the countercurrent heated gases to the top of the charge. Therefore, since the surface of the charge varies directly with the diameter, capacity likewise varies with the diameter. And since within reasonable limits the greater the kiln length the more the transfer of heat from gases to material, efficiency therefore, depends on kiln length. Another factor, however, that of the proportion of kiln volume available for combustion and the flow of gases, must also be taken into consideration.

A number of complicated formulas for determining kiln size in relation to capacity have been developed, but at the present stage of the art past performance seems to be the only reliable criterion. Even this criterion is not always of certain value when it becomes necessary to design a kiln for an entirely new use, although a comparison of capacities on kilns treating materials of somewhat similar nature, or even of different nature, proves helpful and may be all that is necessary. In some cases, however, this is insufficient and the only way to proceed is to make all possible calculations and then compare the results with actual performance data and previous experience.

As an example of some typical capacities being obtained in kilns in small, medium and large size, Table I lists diameter, length and range of capacity on dry process cement, wet process cement, and lime. The larger sizes of kilns are not ordinarily used in either dry process cement manufacture or lime burning. The last column of the table lists appropriate sizes of coolers to be used with each of the several sizes of kiln.

The question of kiln length is one which is being discussed considerably at the present time. Certain kilns of great length have definitely been shown in operation to be longer than desirable while, on the other hand, other kilns are known to be too short for maximum efficiency. Even with





Modern cement kilns, the upper being riveted and the lower welded; note particularly supporting bearings and drive arrangement

materials of very much the same chemical nature, variation in physical characteristics will sometimes be sufficient to make a kiln of ideal size in one location improper for another location. Another efficiency factor to be considered in determining kiln length is whether or not some use of the waste heat at the cold end is to be made in waste heat boilers, in preheating the material or some other application.

A comparatively new development is the use of predryers for wet materials and preheaters for comparatively dry materials. Although such equipment is hardly out of its infancy it is nevertheless being tried out in several plants. Some shortening of the kiln shell is thus possible.

Not only the length of a kiln enters into the time the material remains in the shell undergoing treatment, but also the slope and speed of rotation. Considerable experimenting has been carried out in determining treatment time. A similar material to that to be treated can be fed to an operating kiln and the actual time of travel obtained but the result, it should be noted, is correct only for the particular kiln used. Nor does it apply for a material of different nature. Tests carried out by the U. S. Bureau of Mines and summarized in a bulletin, "The Passage of Solid Particles Through a Revolving Cylinder," have yielded several formulas which check well with performance data. The formulas take into account different diameters, restrictions (both of natural formation and intentional), slope of kiln and speed of rotation. They may well be used in calculations for kiln size.

The choice of a proper slope for the kiln is so closely related to the speed that it can hardly be determined independently. Although occasionally a special use for a kiln demands a particular slope, usually the slope and speed are considered at the same time. A kiln set so as to have a flat slope may be revolved at a high speed and yet give the same result as would be obtained if it were set with a greater slope and revolved at a proportionally lower speed. In other words, the criterion is time of travel through the kiln. By far the greatest number of kilns are set with a slope of ½ in. per foot, so that the speed becomes the factor which determines the retention time. Speed must not be too great and is generally in the range from 25 to 30 ft. of shell periphery per minute or, say, 1 r.p.m. for an 8-ft. kiln. Such a speed may be exceeded in some cases, which is permissible if it can be done without bad effect. A much higher speed, say, from 100 to 150 ft. per minute peripheral speed of the shell is used with dryers and coolers, which is perfectly suitable, considering their lighter duty and more nearly balanced load.

Heat Transfer in Kilns

Various methods have been employed to facilitate transfer of heat from the hot gases to the cold material at the feed end of the kiln. One of the commonest is the installation of a veritable maze of chains installed from a point a short distance from the feed end and continuing for a suitable distance through the length of the shell. Such chains are particularly useful for wet operation. The chains, being secured to the shell are alter-

Table I—Typical Sizes and Capacities of Kilns and Coolers

Diameter, Ft.	Length, Ft.	Capacity: Cement, Dry, Bbl.	Capacity: Cement, Wet, Bbl.	Capacity: Lime, Tons	Coolers, Dia. x Length, Ft.
6	60	220–225	130–140	23–27	4 x 40
9	175	1,050–1,250	950–1,100	125–150	7 x 80
10	300	.....	1,800–2,200	.....	9 x 100

nately dropped into the wet charge and then brought up again into the path of the heated gases. Thus heat transfer takes place both from the hot chains and from the gases to the material on the chains. The most difficult part of chain installation is in determining the correct position and length of the chain section. It must not cause material to backspill out of the feed end of the shell; and if it is too long the material will be completely dry before reaching the end of the chain section and possibly additional water may have to be added to the charge to permit using the chains most effectively.

Experimental work by kiln users on operating kilns has been carried on from time to time, in which the attempt has been to show the heat in the flue gases, heat absorption of the material being treated and chemical state of the material at various cross sections in the kiln. Some of these tests have been conducted with considerable care and the curves plotted have shown a marked resemblance to each other, considering the differences in the various kilns on which the tests were conducted. Even with these results, however, available handbook information so far is incomplete and the estimation of proper kiln length is still empirical. This is not to say, however, that an accurate theoretical basis for determining kiln reactions and length may not some day be available.

The problems in designing rotary coolers and dryers are very much the same as those in kiln design, although considerably easier. The calculations of heat transfer, length of travel and other factors are relatively simple. Fewer unknown quantities must be estimated. The duties of a cooler and a dryer being nearly the reverse of one another, their design problems can be treated as essentially similar. However, in the drying of special materials requiring protection from the combustion gases, which hence must travel within a central tube or annular space between cylinders, additional difficulties in the determination of the heat transfer are certainly involved.

Mechanical Design Problems

Although it might be expected, with the great bulk of information that is available on the strength of materials and with well recognized calculation methods for the strength of machine elements, that calculations for the mechanical design of kilns and kindred equipment could easily be made, such is not the case. A kiln might be considered as a revolving beam but it is a revolving beam of extreme weight to which heat is applied in a more or less unpredictable manner. Therefore, although the kiln might be designed as such a non-uniformly loaded beam, supported at two or more points, with overhung ends of equal or unequal length, nevertheless the calculations would show the need of plate thickness considerably less than has been proven necessary by experience. Therefore, a kiln is either designed employing a favorable elastic limit for the plates, naturally much lower than that allowed in handbooks, or it is designed by the usual methods of calculation, employing a high factor of safety.

Take, for instance, a kiln 9 ft. in diameter and 175 ft. long, lined with brick. Calculations would give a proper plate thickness between $\frac{1}{16}$ and $\frac{1}{8}$ in. depending on the thickness of brick lining, the weight of material being treated and other factors. Actually the minimum thickness of plate for such a kiln under ordinary conditions is $\frac{1}{2}$ in.

Deflection has a very real bearing on successful kiln operation. If the theoretical thickness of plate were used the kiln would naturally deflect considerably more than theory would indicate and would hence be jerky in operation and troublesome in regard to length of life of brickwork. Since kilns have never been made of such extremely light plate, it is impossible to predict what other troubles might also arise in operation.

In determining the anticipated performance of a kiln shell, it is necessary to make calculations for bending stresses, deflections and shear. In doing so it may be considered that the brick lining adds slightly to the strength of the shell but, on the other hand, the application of heat inside probably robs it of some of its strength, especially if the brick lining is allowed to become thin, even in spots. The fact that the shell revolves means that the stresses are constantly undergoing change and this condition must be taken into account although no theoretical basis for doing so is available.

Table II—Typical Plate Thicknesses for Kilns and Coolers

Equipment	Size, Ft.	Number of Supports	Plate Thickness, In.
Kiln	6 x 60	2	$\frac{1}{4}$
Kiln	8 x 125	2	$\frac{5}{8}$
Kiln	9 x 175	2	$\frac{1}{2}$
Kiln	10 x 300	5	$\frac{3}{4}$
Cooler*	3 x 30	2	$\frac{1}{8}$
Cooler*	6 x 60	2	$\frac{1}{4}$
Cooler*	9 x 100	2	$\frac{5}{8}$

* Or dryer.

When rotary kilns having three or more supports with unequally overhung ends are under consideration, there appears to be no formula in existence capable of giving the stresses. Multiple-tire kilns, therefore, can be designed only on the basis of past performance. Even in the case of two-support kilns, calculations must be tempered with a heavy flavoring of practical experience to permit coping with some of the contingencies that occur in kiln operation. For example, where linings get too thin in spots or fall out entirely and the shell becomes too hot, it tends to bow or warp. With a shell in this condition the reactions encountered are totally unpredictable. For example, on a riveted shell the rivet heads on the outside may pop off, indicating tension in the rivets, despite the fact that such tension, apparently, should not exist. Various other factors also may cause warped or bowed kiln shells. Lack of care in shutting down the kiln, sudden loss of power supply, or possibly having the kiln standing idle in the hot sun may yield this undesirable result. If the warp or bow is not too great, the common method of straightening the shell is to apply heat to the inside of the bow and carefully revolve the shell.

From the foregoing it is clear that stress calculations are of little value in determining shell thickness. Table II lists a number of representative plate thicknesses used for various sizes of kilns, coolers and dryers. It will be noted that the thickness is influenced by the number of supports and by length of span between supports, as well as the loading and other factors not evident from the table.

Tire Calculations

To strengthen the shell against shear and help in distributing the tire reaction over a length of shell, it is customary to use several reinforcing or wrapping plates placed between the shell proper and each tire. These act very much in the same way as do the cover plates on built-up girders and prevent the collapse of the shell at these points. Most of the reaction is taken by the tires since the reinforcing plates are not nearly strong enough to do the job alone but they do assist in distributing the reaction and straightening out the high spots in the stress curve.

Reactions encountered in tires are several, including compression caused by weight, tension caused by the resistance of the tires to expansion of the shell and to holding the shell in a true circle. In addition, tires must resist the action of roller adjustment. The design of the tires involves a number of unknown factors such, for example, as the exact weight to be supported. Although the weight of the shell and lining can be calculated to a nicety, the thickness of the coating of material built up on the lining is unpredictable, as well as the amount of material which may dam up from time to time. Furthermore, it is impossible to determine the temperature to which the tires will be subjected and the degree of misalignment of the rollers which may occur through improper adjustment. Here again the proof of the pudding has shown that a much greater tire strength is necessary than would appear from calculations.

In tire design, of course, the character of the material used must control the allowable pressure per lineal inch. Furthermore, the shape of the tire section is also an influencing factor. As a rule, tires are supported on a number of blocks or plates shaped to the circle of the shell, and the tire may be made a tight or loose fit, depending on the thickness of the blocks. Whether to use a tight or loose fit is a matter of opinion at present. Formerly tires were riveted through the blocks, reinforcing bands and shell and had to be fitted tight. The long tire rivets required to reach through so much metal were a source of continual trouble since alternate expansion and contraction caused by starting and stopping the kiln, even infrequently, caused the rivet head to pop off. Replacement was a serious job since the lining had to be removed in order to drive the rivets. Today practically all tires are of rivetless design and so may be either tight or loose.

Another factor in tire design which has been shown desirable by experience is the provision of an air space, made possible by the use of blocks. Tires mounted directly on the reinforcing bands without arrangement for air circulation have failed, even when of the same section as satisfactory tires using an air space. Tire fastenings must be made sufficiently strong to resist the longitudinal thrust transmitted to the tire by the rollers and caused by adjustment of the rollers to compensate for the kiln pitch.

Various changes in design of supporting or roller bearings have occurred as practical operation has dictated improvements. Originally bearings were of the solid grease-lubricated type and on the small kilns then made probably did a fair job. As kilns began to grow in size, a grease-lubricated support with four rollers in an equalizing cradle was tried, but left much to be desired. Today, customarily only two rollers are used to each tire, but with the bearings positively lubricated with oil. Power consumption is lower, both because of better lubrication and because of the release from the binding action of four rollers.

Due to the fact that the roller bearings must support great weight, operate at extremely low speeds and contend with radiated heat, there seems to be no acceptable method of calculating their proper size. Again, if it could be calculated, the indicated bearing size would probably be much smaller than has been dictatd by practice. A similar situation occurs in computing the necessary face widths for rollers and tires. In the design of the bearing pedestal, bed plate and some of the other parts making up a supporting bearing, however, calculations are acceptable since most of the reaction is compression. A particular point in the design of these parts is to secure the accessibility necessary for repairs. It should be noted, however, that it is not possible to predetermine the end thrust of a kiln shell, which must be taken care of by means of thrust disks or washers in the supporting bearings and by the use of a thrust bearing stand which is separate from the supporting bearings but on the same bed plate. This reaction varies so greatly under various circumstances as to defy calculation. Even with the rollers carefully adjusted, an end thrust is added to that due to the pitch by the adjustment and this must be taken into account although it is unpredictable.

The proper location of tires on a two-support kiln depends on the loading, of course, but where a shell is lined with 9-in. brick in the burning zone and 6-in. brick in the remaining length, most designers place the tires so that 24 per cent of the shell length overhangs the support at the feed end, 16 per cent overhangs at the discharge end and 60 per cent is between the supports. With an equal thickness of brick lining throughout the shell, the overhangs should theoretically be equal or each 20 per cent of the length of the shell. However, there is always the possibility of ring formation at various points in the shell and the most likely location for this contingency must be considered. Furthermore, variation in the heat conditions at various points must be considered, especially in kilns used for special processes. There are no general rules for the position of supports in multiple-support kilns. With dryers and coolers, overhangs are generally equal, with 60 per cent of the space between supports.

Drive and Foundations

Design of the drive of a rotary kiln, again, requires the judicious application of the factor of safety. Theoretically, it should be possible to calculate the power required to drive a kiln, taking into account the raising of the material load, the overcoming of friction in the bearings, between the roller and tire faces, and in the driving gear itself, but this has not proven possible in practice because of the formation of rings in the shell, maladjustment of the supporting bearings, the inaccurate setting of the ring gear and pinion, and friction due to the use of sealing rings at the ends, together with other factors. Furthermore, formulas for figuring the strength of gears, shafts, bearings, etc., moving at such slow speeds as are encountered in kiln operation, are not in existence.

The design of the kiln accessories such as the firing hood, sealing rings, stack, safety guards, feeder mechanism and other parts, does not present the same difficult problems noted above. The ordinary attributes of the competent engineering designer, plus a knowledge of the requirements for each part, suffices.

No great difficulty is experienced in calculating kiln foundations. Knowing the weight of the kiln and the bearing value of the soil, the foundation can be calculated readily, except for the fact that the reaction due to driving the kiln, and its angle of application must be estimated. Another reaction closely allied to the first, the lag of the shell which is transmitted through the tires to the supporting bearings, must also be estimated and like the drive reaction, this is not a downward force. Vibration inherent in such heavy revolving equipment must also be considered. The best way to take care of this situation is by the use of enormous masses of concrete, particularly for the foundations of the driv-

(*Please turn to page* 333)

Foundations and Supports

BY CHESMAN A. LEE, engineer of Darling & Co., Chicago, whose experience ranging from engineering student through millwright to designer, installer and trouble man on materials handling and general plant equipment, gives him a rare background for this discussion of a subject foreign to the experience of most chemical engineers.

DESIGN FOR OPERATION

DESIGN of complicated foundations and equipment supports is undoubtedly a job for the specialist, but there are many cases which the plant engineer of average experience should be competent to handle. In putting down concrete for equipment foundations the first problem is to determine the soil bearing pressure, an allowable figure for which for various kinds of soils can be found in engineering handbooks. Knowing what load per square foot the soil can support, the problem then is to provide sufficient area in the footing to distribute the load, and so to locate it as to get uniform unit pressure. Don't forget that soil itself is compressible, and that it can shift. Nevertheless, most soils require only a sufficient bearing area to support any load.

Soil that has been dug up and replaced, or filled land, may be good for only about a ton per square foot, but in one case where supposedly weak soil had supported vibrating machinery for several years the writer used a 2-ton per square foot loading for the support of an important tank. Since the installation was successful, presumably the supposition was correct that the vibration had compacted the soil.

It goes without saying that unless a certain amount of shifting will not damage the equipment, footings must go below the frost line. Another thing that must be anticipated is that poor drainage may make the soil weaker at certain times of year. On the other hand the Biblical warning against a foundation on sand is unfounded when it applies to footings for straight compression. Sand under this condition is very strong.

In one case the writer heard the claim advanced that since the strength of the soil was in doubt, certain important footings should be put deeper. The idea was not that a different soil would be encountered, but that the soil would be stronger for the greater depth. There is no basis for this claim. To go below the frost line, and below any fill, is to go deep enough. Incidentally, there is no parallel between the setting of footings and of fence posts. A footing depends for its lateral stability upon its sufficiently broad base, and not on the lateral resistance of the soil.

Good concrete is necessary for footings to resist disintegration, although it need not be exceptionally strong as the soil is the limiting factor. Quite a lean mixture is suitable, provided that it can be handled without adding more than 7 gal. of water per bag of cement. The writer prefers a 1:2:4 mix with not over 6½ gal. of water per bag, and sees to it that the concrete is well compacted.

Regarding reinforcement, no steel covered with thick rust should ever be used. The practice of reinforcing with old pipe is strongly to be condemned, although used rails and structural steel have more to recommend them. With the low footings that a plant man should attempt, however, there is seldom need for reinforcement anyway.

Sometimes a concrete foundation must be put in, provided with anchor bolts that must match a piece of equipment. A simple way to make sure that the bolts will fit is to make a template of light material, stiffened with diagonal bracing. Holes are drilled for the bolts in the template and the bolts, assembled with pipe spacers, are secured to the template as in Fig. 1. Then they are concreted in, leaving a little space for grouting. Since the spacers are slightly oversize, the bolts can be sprung enough to take care of small misalignment.

Another useful trick in bolting down equipment, if it must remain tight against vibration, is to provide extra length bolts with pipe spacers as in Fig. 2. The longer bolts hold more tightly since they stretch slightly and have more resilience. On this account, they will not fracture from "crystallization" at the root of the thread. When cork or rubber insulation is used to absorb vibration, incidentally, it is a sensible precaution to install an electrical ground to avoid trouble should an accidental ground occur in the motor.

Tanks are such commonplace chemical plant adjuncts that many people are inclined to take them for granted. C. O. Sandstrom's recent series of articles on tanks and, particularly, bins (*Chem. & Met.*, Dec. 1938, Jan. and Mar. 1939) showed some interesting savings in their selection and design. A number of points in regard to tank supports are presented below.

Tanks should be supported so as to minimize local bending stresses, for thus the seams will stay tight longer. Simple as the rule is, it is more often honored in the breach than in the observance.

The distribution of metal in a cylindrical tank is such as to give it natural stiffness and suggest easy means of support. Suppose the plant has secured a second-hand tank car tank of moderate thickness. A common support is at the quarter points as in Fig. 3*a*—a perfectly satisfactory

method provided only that the reactions are not permitted to deform the tank. The 120-deg. cradles shown in (*b*) should be used, not the "chocks" of (*c*). Although the tank was not originally supported as suggested, it is well to remember that it would not have been offered for sale if it still had its original factor of safety.

In Fig. 4 is a common type of support for a horizontal tank, employing brackets on the side of the shell. To avoid eccentricity with such a support, the reactions should be as nearly tangential as possible.

Vertical tanks with conical and dished bottoms offer difficulties in support which do not seem to be well understood except by specialists. One common error is to support the tank on legs or feet under the bottom itself; another, to place the brackets on the sides so as to introduce quite a bit of eccentricity. A vertical tank is correctly supported when a vertical through the center of gravity of each leg falls on the side of the tank so that the full depth of each side sheet acts to transfer the load. For example, Sandstrom (*Chem. & Met.*, Dec. 1938, p. 684) described a neat and fundamentally sound support, consisting in extending the side sheet down below the bottom as a continuous support.

Occasionally it appears to be necessary to support a tank on eccentric brackets, as in Fig. 5. In such a case the moment due to the eccentricity should be calculated and stiffeners added as required. Otherwise, watch out for the "factor of safety!" For slight eccentricity it is sufficient to extend the brackets vertically. A point worth noting is that the junction of the side and cone bottom is naturally stiff and so makes a good location for the feet of brackets.

A rectangular tank is generally set on its own bottom, but when such a tank must be supported on a frame smaller than itself—as on a scale frame—then beams or brackets must be added to end under two opposite sides, as in Fig. 6. The sides *A* and *A'* act as plate girders to support the sides *B* and *B'*, being themselves supported by the beams shown.

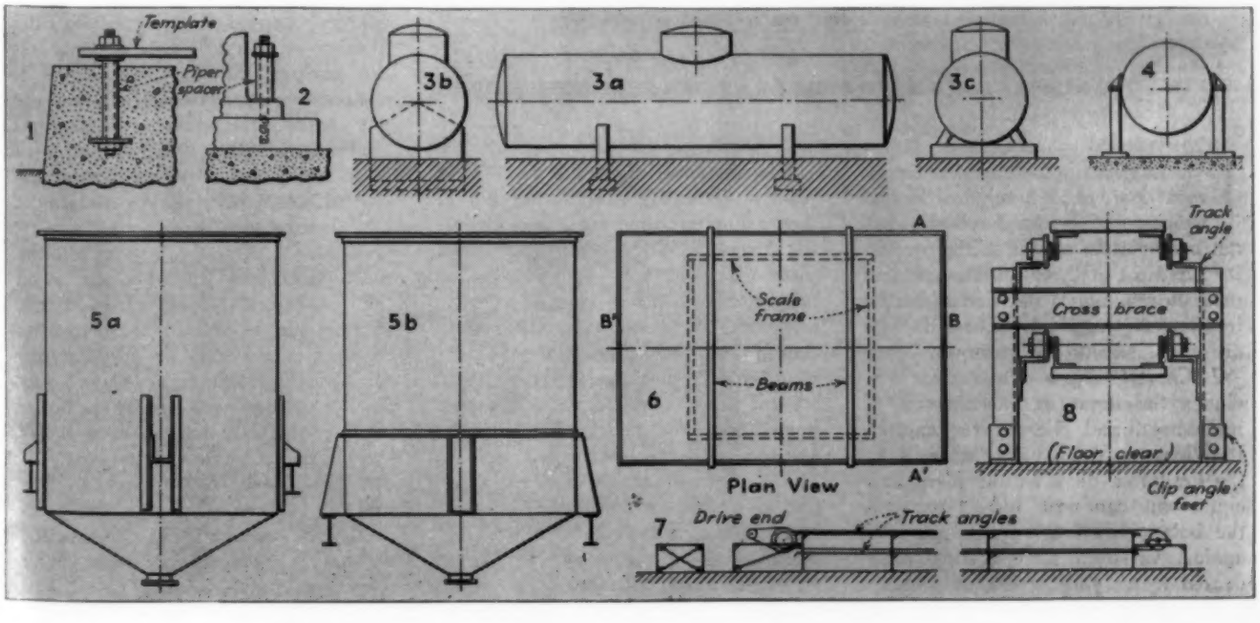
Up to this point the equipment discussed has involved no torsional stresses due to drives. In considering machinery supports, the first principle is the obvious one that for every action there must be an equal and opposite reaction. Hence, the system of forces *must close*. To explain this, consider a belt driven machine. There is a "center pull" between motor and machine transmitted not only *to* the foundations, but also *through* the foundations, so as to join again. The system of forces must in every case make a closed loop. It follows that a direct path for reactions makes for rigidity. This principle affects supports for all drives and also applies to conveyor frames.

Conveyor engineering is a special field and should not be invaded lightly by the plant engineer. However there are some simple cases where it is perfectly reasonable to requisition the required amount of apron or other type of conveyor, and build the drive and a light frame to suit. The drive, including the head-shaft, may be considered as a unit. The support frame should be so braced as to be rigid under the torsional pulls of the drive and the longitudinal pull from conveying. Light diagonal bracing, as in Fig. 7, is more effective for this duty than are stiff corner brackets. At proper intervals depending upon the load, cross-frames or "bents" are installed to support the stringers which, when connected solidly to the drive-frame, require no additional longitudinal bracing. In fact, diagonal bracing longitudinally would develop truss-action and thus would be a liability in case of floor settlement. The cross-members of the bents should have stiff connections as in Fig. 8, but need no diagonal bracing.

It is surprising how often one will see a piece of equipment such as a cycloidal blower mounted on a fairly well braced wooden support and driven by a medium-centers belt from a motor mounted on a separate, fairly

Figs. 1 and 2—Two good foundation bolt ideas
Figs. 3 and 4—Horizontal tank supports, good and bad (the latter, 3 c)

Fig. 5—Supports to minimize effect of eccentricity
Fig. 6—Supporting a flat bottom tank on a scale
Figs. 7 and 8—Bracing for an apron conveyor



well braced support. The writer has seen belt trouble eliminated by adding direct bracing between the two supports as in Fig. 9. The point is that a heavy center pull is best resisted when reactions are not taken to the floor.

A similar case may be found in bucket elevators which are often driven from a motor not mounted on the casing. Sometimes bracing at the head is necessarily sketchy, but it will not be sufficient unless so installed as to resist the twisting moment introduced by drive. The writer has seen drives the main belt of which continually slipped off under moderate overloads. After several years of this difficulty the operators had become reconciled to the condition. Inspection shows that there was nothing that could not be corrected by the bracing indicated in Fig. 10. Incidentally, the motor rails were bolted through a wooden floor to the tion. Inspection showed that there was present to permit some twist; hence the motor pulley also was out of line.

Reciprocating feeders under bins combine torsional and reciprocating loads and should be braced accordingly. The reciprocating load is obviously best taken care of by bracing the feeder frame to the bin itself. It may be of some assistance to discard the fly-wheel which usually comes with such a feeder. This remark applies especially in case of a chain drive. A fly-wheel is no asset unless its speed can vary as the load comes on, and the standard motor is essentially a constant speed machine. Diagonal bracing is required.

The solutions outlined above do not cover all the cases which may arise. However, the general principles involved should aid with other problems. Equipment once installed must be used for a long time and it is worth while to analyze each case and see how best to support it.

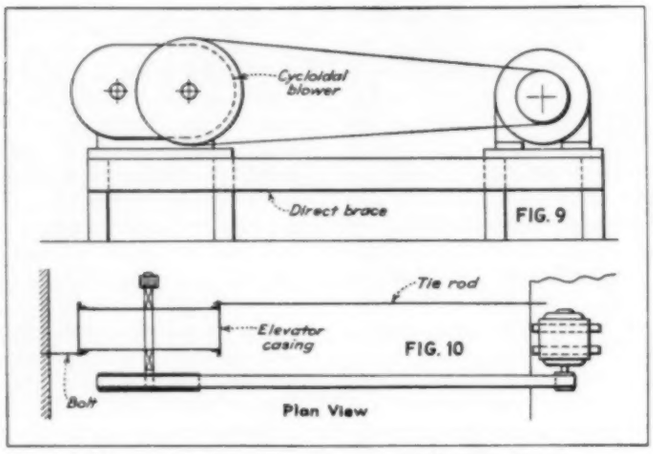


Fig. 9—Direct bracing for a troublesome drive
Fig. 10—How an elevator drive was cured of belt trouble

Non-Process Factors in Design

BY PAUL D. V. MANNING, consulting chemical engineer and Pacific Coast Editor of Chem. & Met., *the author of the first article in this series. Dr. Manning here summarizes some of the apparently extraneous factors affecting plant and equipment design which have a marked effect on low-cost operation*

DESIGN FOR OPERATION

IN DESIGNING a plant and its equipment there are a number of factors which must be considered although not immediately related to the process itself. Most of these must be studied prior to reaching a decision as to the location of the plant. These factors are classified into five groups.

1. Capital Costs—This class includes the items of amortization of investment, and charges for capital. Its effects on design is principally in the limitation on what the plant and equipment can cost and it requires the balancing of charges for capital against variation in operating costs caused by varying investment costs.

For instance, take the case of a process requiring evaporating equipment. For the same given investment, the lower the first cost of the equipment, the greater the number of evaporator effects which can be used and therefore the greater the reduction in the amount of steam and water required for operation. Thus the total cost of production is lowered by two items, first lowered capital charges and second, decreased operating costs. There is in this case increased incentive to design the equipment so that every dollar invested is a working dollar. Since the heating surface of an evaporator is the direct working part, design of this part of the equipment so that the other parts are simple and cheap, and a design that makes possible high rates of heat transfer per square foot of heating surface, will result in lowest possible capital charges.

In making a decision as to the number of effects in an evaporator installation, the increase in capital charges caused by increasing the number of effects is balanced against the savings in cost of steam. If boilers are already installed and are not badly overloaded, the capital charge on the boiler equipment should be omitted in calculating the cost of steam because the investment has already been made.

Where a new boiler installation must be made to fit the plant, as in the case of an entirely new plant, capital charges should be figured on steam in both cases of the comparison, since additional stages may effect a saving in the cost of the boiler installation itself due to lower boiler horsepower requirements.

2. Laws and Regulations — The items in this classification have increased in number rapidly during the past several years. Labor is no longer related so much to local conditions

as it is to unions. At present control of labor by unions has almost the effect of legal restrictions or regulations. In addition to Federal regulations, most states have their own laws, some of which have somewhat onerous and costly restrictions relative to labor.

Other items closely related to labor are safety regulations, compensation insurance and payroll taxes. The effect of all these regulations is to favor the design of equipment that is safe, foolproof, as nearly automatic as possible, and since such "overhead" charges caused by these regulations do not increase in direct proportion with the skill of the workers, the tendency is to design equipment that operates with a smaller number of men, but of higher types.

In all cases thorough study of every phase of labor regulations must be made and a summary of desirable limitations given to the designer before he starts his work.

Other laws and ordinances governing permissible types of buildings and erection of equipment must be considered before starting designs of equipment. Such regulations differ markedly in various locations owing to fire and earthquake hazards.

Obsolescence and depreciation have moved into the classification of those things controlled by law or government bureaus. The Internal Revenue Bureau determines the deductions allowable for these items. Prior to design, it is wise to give some thought to this matter and also to what might be termed "obsolescence or depreciation of location." The question, "How long will the location of this plant be as valuable as it seems now?" is an important one.

Equipment obsolescence and depreciation vary considerably with the type and variety. Motors and electrical equipment may carry one rate, and other equipment another. An analysis of all types of apparatus to be used in the process should be made, if possible with the help of a tax expert, prior to beginning the design.

3. Basic Process Essentials—This class includes such materials and services as fuel, steam, power, water supply, sewerage and waste disposal. Certain fuels that are not generally considered useful because of their low quality may frequently be used with properly designed equipment. In the case of one plant built in an Oregon Coast lumbering town where hog fuel was cheap and abundant, this material was used as a fuel. Sometime later it was found possible by installation of a new type stoker, to use an extremely low grade of coal at a good saving.

In the case of smaller plants, there is often a chance to save money both on initial investment and in operation by working out an agreement with an already existing plant for the purchase of steam or the operation of boilers on a cooperative basis.

Power costs may be lowered in certain cases by generation of part of the power requirements. Where process steam is used, bleeder turbines can furnish both power and steam at almost any pressure. Such installations are too numerous to require illustration.

In some locations, water supply is a difficult problem. Cooling towers and evaporative condensers may be solutions to water shortage, while settlement, filtration or other treatment may be needed with low-grade waters.

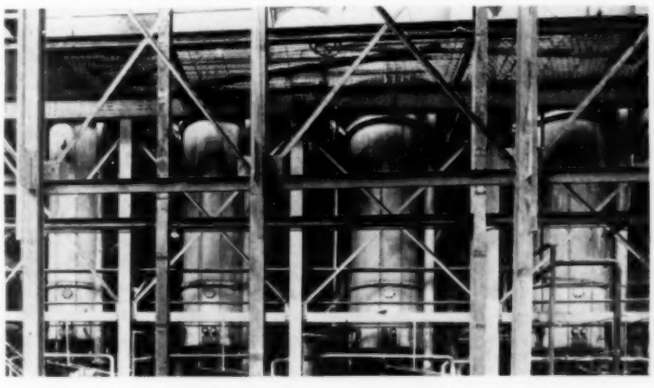
Sewerage and waste disposal cannot be overlooked. The writer knows of instances where plants have been installed and almost ready for operation before the sewer was even considered.

4. Location—Climate has an important influence on design. Heating of buildings and equipment, installation of air conditioning equipment for the plant or for furnishing properly conditioned air for handling or conveying powdered material, the design of equipment so it can be drained to prevent freezing, are all important problems.

5. Fabrication, Shipping and Erection—Technique in welding has now reached such an advanced stage that fabrication is considerably simplified. This permits the shipping of shapes, pipes, etc., to the job for final fabrication virtually during erection. Equipment that must be fabricated in shops should be designed so that it can be handled easily and transported without undue cost influenced by its shape, size and weight.

Attention to all of these points will aid the designing engineer to the end that the process will operate at lowest possible cost.

Number of evaporator effects is fixed by balancing the cost of additional effects against resulting steam savings (Illustrated is a Swenson five-body black liquor Quad)



HEAVY ROTARY EQUIPMENT

(*Continued from page 329*)

ing gear. Although there are other reactions, they are adequately cared for in making the foundation sufficiently massive to take care of the known reactions.

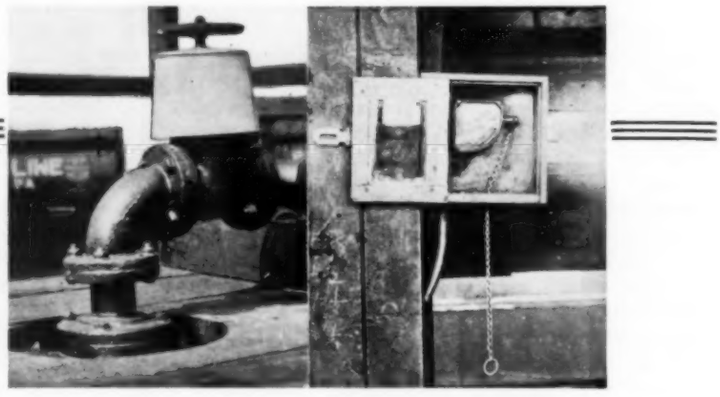
Although the remarks of the last few paragraphs have been confined to kilns, they apply in the main to dryers and coolers as well. In kilns the various conditions and reactions are so much more severe than in coolers, dryers, roasters and retorts, that the kiln may well serve as a model for these smaller pieces of rotating machinery. The remarks concerning foundations are particularly applicable, because, as a rule, the smaller machines revolve at higher speeds with consequent greater vibration.

It is perhaps unfortunate that the greater part of the data on kiln design which exists in the hands of designers has never been correlated and published. Until this is done, no adequate method of kiln design exists for those who lack access to the records of experience.

Safety Considerations in Design

BY W. DEAN KEEFER, chief engineer and director, Industrial Division, National Safety Council, Chicago. Mr. Keefer has spent many years in safety work, has written numerous articles on the subject and has a prominent position in the American Society of Safety Engineers.

DESIGN FOR OPERATION



Safety features may be incorporated into chemical equipment much more easily when it is in the design stage than after it has been built. At right are shown a metal shield to cover stem and bonnet of an acid valve and an emergency cut-out switch that may be locked, requiring investigation before restarting

NO MATTER HOW WELL industrial equipment is designed and constructed, if a worker is injured while operating it, the designer has at least partially "fallen down on the job."

In the days when labor was cheap, accidental injuries to workers were not given very much consideration. Now, however, since each injury costs the employer an average of $200 just for compensation and medical expense, the accident problem has become sufficiently important to call for continuous and intelligent executive action. Thus, in well-managed establishments, every employee from the president down to the most lowly laborer, is required to do everything in his power to cut down the frequency and cost of accidents. And though many persons do not understand it, there is *something* that every individual in the organization can and should contribute toward the attainment of this objective.

Causes of Industrial Accidents

Let us consider very briefly the accident problem as a whole. It is generally recognized that accidents don't simply happen; they are *caused*; and if we are to prevent accidents, we must eliminate the causes.

What, then, are the causes of accidents in industry? The two major causes are: (a) faulty environment, and (b) faulty behavior of individuals. The first of these causes is exclusively responsible for about 20 per cent of all industrial injuries. Another 20 per cent, approximately, is due exclusively to the second; and the remaining 60 per cent, to a combination of both.

Eliminating Causes

In general, faulty environment is corrected by engineering. This involves the application of engineering principles in the design, location and construction of buildings, equipment and processes; in providing illumination and ventilation; in the provision of efficient goggles and respirators; in corrective maintenance; and in the installation of safeguards for hazards that have not been eliminated through design and construction.

Human behavior, on the other hand, can be controlled for the prevention of accidents by a combination of means that have come to be grouped under the heading "education." This includes such activities as physical examination of applicants for employment, proper placement of men, job training, supervision, and discipline at rare intervals when necessary.

As an example of faulty environment take the case of Tony's death that cost the company $7,150 in cold hard cash. His widow got $5,000 compensation; $2,000 worth of goods were spoiled; and it cost $150 to repair the damaged equipment.

The accident report read: "The drip-pan under the refrigeration coil fell on Tony's head and killed him instantly."

When the chief engineer, the master mechanic and several others investigated the accident, they remembered that several months earlier they had installed this drip-pan to eliminate the cause of a puddle on the floor that resulted when moisture from the air condensed on the coils. It had been "one of those little jobs" that didn't require blueprints. A couple of strap hangers had simply been suspended from the coil, and the drip pan had been attached to it. But the thing happened that no one had foreseen; the dripping water had frozen in the pan, and when the pan fell, it came down with the coil plus about a ton of ice. It sure was tough on Tony. He had not been to blame in any way, but the men who had installed the drip-pan learned a lesson about faulty environment and "man-traps" that they did not soon forget.

Faulty behavior was evident when, several months after Tony's death, Sam ——, employed in the same plant, suffered severe burns about the face and neck because he did not use the lock and key that he carried in his tool box. He had closed the acid valve all right, and then he went behind the

agitator to take apart and repair a flange in the acid line. The operator, coming in and finding no lock on the valve, thought that Sam had finished the repair job. So he opened the valve, and Sam was sprayed with acid from the open flange. Fortunately, he was wearing goggles; otherwise he might have lost the sight of both eyes. This, the investigating committee decided, was due entirely to Sam's own negligence in failing to carry out the instructions that he clearly understood —to his failure to use the equipment that management had provided for his own protection.

The causes of Tom ——'s injury, however, were somewhat more complicated. He had come into the machine shop from the nitrating department to see his friend Bill, who was operating a power press. Tom was tired and leaned his arm on the bed of the press; and then to get still more comfortable, he placed his foot on something that was elevated to just about the right height. But unfortunately for Tom, that "something" happened to be the operating treadle of the press, and when the ram descended, off went three digits from Tom's right hand. Sure, it was Tom's own fault. The investigation report indicated that he had no business in the machine shop, and if he had been on the job, he wouldn't have been hurt. On the other hand, neither would he have been injured if a suitable enclosure had been installed around the ram or if the treadle had been designed with an off-center prop so arranged that the treadle could not have been operated accidentally.

Education vs. Engineering

Consider a simple hazard like a hole in the floor. If an effort is made to teach the workers to avoid the hole, someone (or worse yet, everyone) in the plant must watch his step and at the same time caution every other person to do the same. Such a procedure is never-ending and wasteful of time and money, for sooner or later someone is bound to forget and an accident is sure to occur. On the other hand, if the floor were repaired in the first place, even though the cost were to run as high as $25, everyone could go on about his job in a much freer and more efficient manner. In other words, if a given accident can be prevented by either of two methods, by education or by engineering, the second method is by all odds preferable to the first.

There are many ways in which engineers and designers can use their technical knowledge, not only for the purpose of increasing operating efficiencies, but also for decreasing accident costs. Correctable hazards can usually be found when—(a) creating plans and specifications for new buildings, machinery and equipment, (b) making plans for changing existing structures, (c) checking purchase orders for new equipment, (d) designing the products of one's own company, (e) investigating accidents, (f) inspecting company property and equipment, and (g) analyzing various jobs and processes.

For example, a certain chemical company recently put up a new warehouse for the storage of some of its finished products. The plans included the installation of an overhead traveling crane. Accepted engineering practice calls for the provision of a walkway at least 20 in. in width for the entire length of the crane runway, but in this particular case, through oversight the width of the walkway did not exceed 10 in. It would have cost only a couple of hundred dollars additional to have doubled the width of the walkway in the original design and construction of the building, but once the structure was completed, the cost would run into thousands of dollars to correct a condition that is hazardous for every man who is required to go up on this runway for maintenance or repair purposes.

Price vs. Safety

Frequently, when purchasing new machinery and equipment, engineers (and purchasing agents, too) are influenced more by price than they are by a consideration for the safety of the men who will be called upon to operate that equipment. For example, in a midwestern chemical plant, there was a price differential of $500 between the highest and the lowest bids submitted by the manufacturers of a particularly complicated piece of machinery, and the executive signed a contract to buy from the low bidder. When the manufacturer had completed the installation of the machine, however, it was discovered that he had not included enclosures for the gears, nor had he provided the series of emergency push-button controls that would enable the operator to stop the machine from almost any position. These and other safety features, it was learned, would have been provided and installed by the other bidders, but the low bidder had taken advantage of the fact that these "extras" were not specifically called for in the original contract. Thus, these extras had to be installed by the purchaser at a cost of several thousand dollars, and when added in a homemade manner, they had the appearance of appendages rather than integral parts of the machine itself. This oversight or desire on the part of someone to save a few dollars resulted in a rather costly and unsatisfactory experience.

One could go on indefinitely citing case after case proving that workers are injured because of the human tendency to shrug off responsibility by attributing accidents to impersonal or uncontrollable circumstances. Still, the fine records of hundreds of industrial organizations stand as an unanswerable argument that safety does bring results. This is particularly true of those establishments where the engineers and designers have included safety as an integral part of their essential duties. Such men who eliminate accident hazards while their assignments are still in the drafting board stage of development are making an outstanding contribution to their employers as well as to the workers in their plants.

Safety Features that May Be Overlooked When Designing Equipment

Exhaust systems for removing dust, gases, fumes and vapors that may be created by industrial processes.

Means to prevent contact with live conductors of electricity.

Means to ground the non-current carrying metal parts of electrical equipment.

Safe access to oiling devices and parts needing adjustment on power-driven machinery.

Enclosures for gears, chains, and sprockets regardless of location.

Handrails for stairs.

Handrails and toe boards for platforms, wall openings, and openings in floors.

Suitable illumination.

Proper marking of valves and controls for immediate identification in an emergency.

Automatic valves to shut off fuel lines to furnaces, etc., if the fuel supply fails.

Means of feeding machines in such a manner that the operator need not place his hands or arms in a hazardous position.

Elimination of shear points between moving and stationary parts of machines.

Means of interlocking the power control on the point of operation on machines while feeding, loading, unloading, adjusting, and repairing.

Installation of gages, dials, and controls where they can be seen and operated easily in an emergency.

DISTILLATION COLUMNS

(*Continued from page 317*)

distribution and to eliminate uneven liquid flow due to small deviations in weir height. Notch widths may be varied in various stages across the weir to obtain desired liquid flow in relation to caps traversed.

Pressure Drop and Slot Opening

Bubble caps may be divided into two types when considering pressure drops: (1) Those in which the slots extend to the bottom of the periphery in the form of open teeth and mounted so that the teeth clear the plate; and (2) Caps in which the slots are closed rectangles with an unbroken band of metal forming the lower part of the periphery. Caps of type (1) are similar to (2), if they are mounted so that the teeth rest on the plate.

Caps and mountings as in (1) operate best at vapor rates such that the major portion of the slots are working, but without vapor escaping in the clearance between teeth and plate. For this type of cap, Rogers & Thiele [11] point out that pressure drop over the plate is equal to the difference in static head of liquid on the outside and inside of the cap (neglecting entrance losses and frictional losses in passages under the cap), and give equations for the prediction of slot openings for triangular and rectangular slots as functions of vapor rate. For the second type of cap operated at a vapor rate such that all of the slot lengths were open, Souders et al.[12] obtain the orifice form of expression for calculation of friction drop.

Difficulties in the exact application of these data to the calculation of pressure drops to design, lie in the estimation of the liquid density and actual mean height of liquid on the plate due to foam formation.

In general, for atmospheric and pressure operation, pressure drops over plates are not a serious design limitation provided the general tolerances with respect to liquid depth and per cent of vapor riser and slot area have been maintained. For vacuum operation, low pressure drop per tray is desirable as pressure drop through the tower may result in a large percentage increase in bottom tower pressure over the low absolute pressure maintained at the condenser outlet. Hence, lower slot submergences are employed for vacuum work and bubble trays having individual pressure drops of from 1 to 2 mm. Hg. per tray represent usual performance.

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PACKED TOWERS

(*Continued from page 321*)

pen?" He then usually decides on some form of automatic device such as a spring-loaded safety valve or the like. His next question should then be, "If this spring-loaded safety valve jams what happens then?" A frangible disk device is usually the next step and because of its almost foolproof simplicity, is generally the correct answer.

Small streams of liquid such as usually go through spray nozzles are prone to blockage, as every practical plant operator knows. Readily attended strainers are too often an afterthought to make them as convenient as is possible.

Deep water-tight curbs on the lowermost floors above which liquids of any considerable value are being handled, are another very practical help to operating personnel.

Convenient desks where logs can be made out, blackboards or bulletin boards for communication between shifts or adjacent operations, are all of considerable importance.

Design for Low Maintenance

The features of design from which a low over-all maintenance cost will result, are generally learned only by long experience. When considering this point, the designer does well to spend time with the maintenance mechanic's helper. He will generally get better pointers from him than from the maintenance foreman. It is seldom that anyone but the maintenance mechanic's helper will recall the sharp corners of angle irons projecting into confined spaces which are difficult of access, even if padded. A designer who takes a little paper man in and out of all manholes and compartments on his drawing board should have a vivid enough imagination to actually feel the flagellation of the sharp edges and too-sharp corners that men often have to traverse.

Almost every door over a manhole or access opening can be profitably fitted with a built-in davit, or, better yet, barndoor type of trolleys with which the door can be swung entirely away from the seat of operations during maintenance work. Such devices invariably pay dividends in longer life of such friable materials as heat insulation and gaskets, not to mention iodine and bandages.

A tall piece of contacting equipment generally has a number of places where liquid of fuming or corrosive nature is trapped after a shutdown. Such spots should be equipped with built-in syphons or drains to enable purging such liquid without messing up heat insulation, floors or anything else.

Hinged bolts (commonly spoken of as tumble bolts) almost invariably pay dividends on manhole covers. Often a dove-tail embedded semi-permanent gasket, costing about half a dollar, will put a $50,000 contactor "back on the line" hours earlier.

Under certain conditions of operation parts of contactors become encrusted with a scale or fouled with a slime which can be hacked or scraped off manually. The designer should always find out whether or not an economical solvent for such material exists and if so, should arrange for a built-in solvent or acid circulating system.

Lastly are the features of design which tend to avoid maintenance altogether. These, of course, are featured in other pages in this issue and include such considerations as thoroughly corrosion resistant materials of construction throughout; control of concentrations, pressures, temperatures, or the like, to avoid deposition of insolubles or any sort of encrustations; choice of flow rates which will keep all suspended matter in suspension and yet not destroy the equipment by abrasion.

In short the designer of liquid-to-gas contacting equipment, like the designer of all other practical chemical plant equipment, should be an entirely fortuitous mixture of operator, maintenance mechanic and engineer.